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1926—1927.

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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

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An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

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This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

LAWS AND REGULATIONS FOR THE PROTECTION OF PUBLIC WATER SUPPLIES.

BY WARREN J. SCOTT.*

[*Read September 15, 1926.*]

The growth of statutory regulations for the protection of public water supplies has been a gradual one, with the result that our statute books in some States contain laws which have grown obsolete or unwieldy in the light of sanitary engineering progress. Water-works men, with their many other responsibilities, are often lax in doing their part toward the correction of existing laws and the passage of necessary new laws along this line.

The practice of placing authority with the state departments or boards of health for the purpose of protecting public water supplies is almost universal among the United States. Some States, as Rhode Island, clothe the department or board with almost no power other than that of an advisory nature; whereas others, as Ohio, grant the department wide mandatory powers. Theoretically, it might be advisable to entrust each state department of health with complete mandatory authority, to be exercised at its discretion, with the power of appeal from the department's decision to the courts. Practically, there are many objections to such a procedure. Changing policies by state departments of health, lack of department personnel for exercise of complete police power, opportunities for discrimination, and opposition to complete state domination, are some of the reasons deciding against such a policy. Moreover, it has been found by experience that often more lasting and beneficial results can be obtained by sound advisory and educational policies on the part of the State than by aggressive use of police-power tactics.

The result of these various considerations of the extent of powers which should be granted to supervisory bodies has led to a mixture of definite state statutes and regulations of state departments of health as the principal legal barriers for the protection of our public water supplies, aided by local ordinances and regulations.

Water-supply conditions in New England, which, I think, are more particularly of interest to most of us here, are very different from those in

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many other parts of the country, but are of considerable similarity among the New England States. In many States, water supplies are known to receive large amounts of sewage contamination, and dependence is placed upon purification methods to produce a safe water, with increasing effort to decrease the pollution or at least keep it within reasonable limits so as not to overload the purification plants. In New England our topography and natural water resources fortunately make it necessary to use but very few water supplies, at the present time, which can be considered sewage-polluted.

This has led to a dearth of water-treatment plants, especially water-filtration plants. New England conditions are such that, except in unusual circumstances, chlorination can best be regarded as a factor of safety rather than as an integral part of necessary purification processes. The absence of water-filtration plants and dependence mainly upon clean watersheds and storage, with chlorination as only a factor of safety, necessitates careful consideration of the best methods of protecting our watersheds.

In Connecticut we have one or two comparatively small supplies with drainage areas wholly owned by the water works, which presents an ideal condition. However, this is seldom practicable for large supplies, and with the growing areas needed for water supplies, the complete depopulation of our watersheds would present a serious problem. Farming by tenants of a water-works management on a watershed entirely under control, does not appear feasible for large supplies. Filtration of supplies would in many cases be preferable, from an economic standpoint, to such extreme conditions. Unquestionably, the number of water-filtration plants is sure to increase, but even in the presence of filtration plants, and certainly in the prevailing absence of them, legal methods of protection against dangerous watershed conditions are necessary.

It is intended to discuss briefly existing state laws and regulations, more particularly in New England, as furnished through the courtesy of officials in the various States.

The December, 1924, JOURNAL of this Association contains a very thorough discussion and summary of Massachusetts laws "relating to water supply" by Mr. Arthur D. Weston, Principal Assistant Engineer of the Massachusetts Department of Public Health.

General supervision of public water supplies is vested in the state department or board of health in Connecticut, Massachusetts, and Vermont. The New Hampshire State Board of Health also has extensive powers and may condemn unfit public water supplies. In Maine, the State Board of Health is not specifically charged with supervision but may condemn public water supplies if shown unfit by chemical and bacteriological analyses. One weakness in this Maine law seems to be that pollution must be found by analysis to exist, before condemnation results. Certainly, if surveys show that a supply is potentially unsafe, even al-

though chemical analyses do not show gross pollution and the water is protected by chlorination, with resulting satisfactory bacteriological analyses, the State Board of Health should have the right to order filtration or other changes without waiting for unsatisfactory analytical evidence. In Rhode Island the State Board of Health acts in an advisory capacity under its general duties, and can exercise certain limited powers.

In Massachusetts rules and regulations by the Department of Public Health are authorized by statute. The Public Health Council in Connecticut is by statute empowered to enact a sanitary code which includes regulations for the protection of public water supplies. The Maine Department of Health is empowered to enact rules and regulations, and has issued very general regulations which it would seem advisable to have enacted into statutes, as they present basic principles rather than guiding precepts. The New Hampshire statutes provide that the State Board of Health may upon request of local parties enact regulations for any specific water supply. Many such regulations have been promulgated. The Vermont Board of Health may enact regulations but has not adopted any for the protection of watersheds. The Rhode Island Board of Health is not granted authority to make rules and regulations.

Public utilities commissions, which exist in various States, are generally empowered to fix rates charged by water companies and to investigate complaints of lack of proper service. In Connecticut a very satisfactory condition exists and there has been no conflicting overlapping of activity by the Commission and the State Department of Health. In Maine a drastic departure from the conditions in most States prevails, in that there the supervision of public water supplies is practically in the hands of the Public Utilities Commission although the State Board of Health has the power of condemnation, as already mentioned. It is worthy of note that in some States, such as Massachusetts, almost all water works are municipally owned, whereas in others, as Connecticut and Rhode Island, a very large number are privately owned.

The laws and regulations of the various States may be classified under: (1) approval of new water supplies, (2) stream pollution as affecting water supplies, (3) contamination by improper sewage disposal, (4) manure contamination, (5) bathing in reservoirs or streams, (6) boating and fishing in reservoirs or streams, (7) condemnation proceedings, (8) cemetery locations, (9) cross-connections, and (10) emergency supplies. The status of New England conditions is discussed under these headings.

Approval of New Water Supplies. In Connecticut and New Hampshire, new water supplies must be approved by the State Board or Department of Health. Charter rights and necessary funds must be obtained from the legislature. Under the general laws Massachusetts requires that new water supplies be passed upon by the Department of Public Health and all petitions to the legislature must be accompanied by recommendations of the department. During recent years, all enabling acts of the

legislature passed in Massachusetts have required that the source of supply be approved by the department. The legislature can act contrary to the advice of the department, given under the general laws, but the source of supply must meet with the approval of the department if the enabling act so requires. The Massachusetts general laws direct the department to consult with and advise towns and cities. In Maine, the procedure is the same as in Massachusetts except that the Public Utilities Commission instead of the State Board of Health is empowered. The State Board of Health can condemn a new supply shown unfit by analysis. Vermont requires that the State Board of Health shall consult with and advise when a new system of public water supply is contemplated. Rhode Island has no requirements in regard to the approval of new supplies.

Stream Pollution. As our cities grow in size, it is likely that we shall see additional New England water supplies drawn from sewage-polluted streams. In this connection, the relationship of supervisory bodies to stream pollution is of interest. In Connecticut the State Department of Health may act where pollution is detrimental to public health, which would include questions of water supply. The State Commission on Pollution of Waters, recently created, is granted wide powers to regulate stream pollution, similar to the State Board of Purification of Waters in Rhode Island. In Massachusetts, the Department of Public Health has general oversight over inland waters and is required to consult with polluters as to the best method of remedy and is also required to publish its recommendations to improve streams. All plans for the disposal of sewage must be submitted to the department for advice. Special laws are in effect for the prevention of pollution of certain streams. Vermont also requires the State Board of Health to consult with polluters as to the best method of remedy. In New Hampshire pollution is prohibited subsequent to 1913, unless approved by the State Board of Health. Maine has not passed any stream-pollution laws except that a law provides that the Public Utilities Commission may pass on and prohibit pollution of water or ice supplies. Certain rivers, however, are exempted from this law.

Contamination by Improper Sewage Disposal. There are statutory laws in all the New England States prohibiting the direct discharge of filthy water, sewage, or polluting substances into public water supplies. Indirect sewage pollution may be cared for in Connecticut by orders of the State Department of Health after a hearing of the offending parties. No compensation to property owners is provided by this Connecticut law. Another procedure in Connecticut is for the water department to secure a court injunction against polluters of a supply, according to a statute which provides for damages. In Massachusetts the department, upon petition, may hold a hearing and issue orders to remedy dangerous conditions. Compensation is provided for. The department may not prohibit structures in existence on June 11, 1897, upon complaint of a city or town, unless the latter will vote to finance the change. The same procedure and re-

striction of prohibition of existing structures as in Massachusetts is provided for in Maine and Vermont, except that later dates are stipulated and that the Public Utilities Commission is specified in the case of Maine. The State Board of Health in Rhode Island, after a hearing, may issue orders to abate dangerous pollution. The New Hampshire state authorities may order a water works to remedy conditions on a watershed under penalty of condemnation of the supply. State rules and regulations for the control of improper sewage disposal can be employed for enforcement by the local authorities in Massachusetts and New Hampshire. Watershed regulations, if adopted as allowed by law, could be used in Maine and Vermont. Similarly, sanitary code regulations are in force in Connecticut. It is of interest that rules and regulations as adopted for Massachusetts watersheds specifically prohibit the following construction on watersheds without approval by the State Department of Health: cemeteries; public or private hospitals for persons afflicted with contagious or infectious diseases; tanneries, currying shops, or other establishments or places where the skin, wool, hair, or fur of any animal is treated; and slaughterhouses or other buildings for carrying on the business of slaughtering cattle, sheep, or other animals; or melting or rendering establishments.

Contamination by Manure Disposal. In Massachusetts, Maine, Rhode Island, and Vermont, the statutes specifically state that the use of manure in the ordinary processes of land cultivation may not be prohibited.

Bathing. Bathing is prohibited in reservoirs and tributaries in all the New England States without qualification, except in New Hampshire. In New Hampshire the original bathing law allowed bathing if not within one quarter of a mile of an intake. This law has been amended, and bathing is now prohibited within such limits as the local and state boards of health may establish. The town cannot act independently of the State Board of Health.

Boating and Fishing. In Massachusetts the statute permits the State Department of Health to delegate the granting of permits to local authorities, and this policy is carried out. Local authorities may make regulations in Connecticut and New Hampshire. Maine has passed special laws with reference to some supplies. Rhode Island and Vermont do not specify by statute.

Condemnation Proceedings. In Connecticut, Maine, and New Hampshire, land may be taken for water supply-protection with court approval. In Massachusetts approval of the Department of Public Health is required for taking, and in Vermont the Public Service Commission grants approval.

Cemeteries. In Connecticut no reservoir may be constructed if within one-half mile of a cemetery, except with the approval of the superior court. Similarly, no new cemeteries can be located near existing reservoirs. No cemeteries after 1908 can be located in Massachusetts on drainage areas of water supplies without the approval of the State Department of

Health. None of the other New England States apparently has such laws.

Cross-connections. New Hampshire has passed a law requiring that all valves or cross-connections with polluted supplies must be of such construction as to permit efficient inspection and testing, and specifies as to testing procedure. Cross-connection regulations in the sanitary code of Connecticut require the elimination of all cross-connections by December 31, 1926, but grant temporary extension if approved double-check valves are installed. None of the other four New England States has yet adopted laws or regulations on this subject.

Emergency Supplies. A town, city, or water company in Massachusetts may take land by eminent domain for emergency water-supply purposes or purchase water for six months, with the approval of the State Department of Health. Emergency valves in New Hampshire must be sealed. The State Board of Health must be notified within 24 hours, if the seal is broken. The New Hampshire State Board of Health is by specific statute granted control over all emergency intakes and may order their abandonment. The other States have no statutes of this kind.

It is seen from this discussion that there is a wide variation in legal methods of protection of public water supplies, even in New England, where no great dissimilarity exists in conditions. There is no doubt a tendency to pass too many laws. On the other hand, there is an increasing popular demand that every undesirable condition must be met with a very definite statute or regulation.

It is probable that in some cases the repealing of some statutes, ambiguously worded, overlapping in text, and legislated at a time when principles of sanitation were less definite than today, and the adoption of clear, concise, and workable statutes would do much to aid the health official and water-works man in the task of furnishing a safe water.

Regulations or sanitary code enactment by a state department of health are undoubtedly a guide in the maintenance of proper watershed conditions, but the foundation of procedure should rest upon legislative enactment.

It is not attempted to set up a code of model laws, which should require the best of talent from the legal and sanitary-engineering professions, but it seems worth while to note the basic requirements for laws for the administration of protective measures for public water supplies.

The immediate charge of water supplies is properly in the hands of local officials. The fact that most small water works have no technical facilities for water-supply supervision, the location of many water supplies outside of the limits of the communities which they serve, and the close relationship between health conditions of the various communities, as affecting each other, have led to the designation of a state body to exercise supervision of public water supplies. In times of water-borne epidemic, the State Department of Health must assume authority, and since much

of the responsibility for the health of the State rests upon that department, there would seem to be no question but that it should exercise sanitary supervision of public water supplies.

The statutes should then place the supervision of public water supplies under the State Department of Health. Similarly, the statutes should definitely state, as many do not, that no new system or source of water supply, nor any change in existing sources of water supply, nor any water-treatment plant shall be constructed without the approval of the State Department of Health. The Massachusetts procedure, which requires that all petitions to the legislature for authority to introduce a system of water supply "shall be accompanied by a copy of the recommendations and advice of said department thereon," also appears desirable.

As already stated, rules and regulations by a State Department of Health are unquestionably of considerable value. Sections 160 and 161, Chapter 111, of the General Laws of Massachusetts, seem to present admirable statutes for this purpose. Such rules and regulations furnish a guide in dealing with sanitary requirements for new establishments on drainage areas, and enable authorities to deal with such conditions as insanitary privies or overflowing cesspools without the necessity for formal hearings on small flagrant violations.

Although no person acquires the right to pollute a water supply, yet it must be remembered that the property owner has certain rights. Certain changes of existing structures may be necessary on account of the location, which would obviously be unnecessary except for the proximity of the property to the water supply, which is, of course, producing revenue for the water works. Such conditions might properly be ordered changed by purchase or financing by the water-supply owners.

It would seem wise to provide by statute, as in Connecticut, that the State Department of Health may, after hearing, issue orders to a property owner on a watershed to remedy dangerous conditions; but there should also be set up legal procedure whereby the property owner should be compensated for extraordinary expense.

The statutes should definitely place with the State Department of Health the authority to order the owners of any water works to undertake necessary improvements or changes in a system of water supply, whether because of danger of pollution or inadequacy of a supply. There should, of course, be provision for appeal from the department's order, and also, provision for methods of financing the necessary improvements.

The State of Ohio has enacted valuable legislation along this line. Sections 1252–4 and 1252–5 of the 1921 Ohio act read as follows:

SECTION 1252–4.

Section 4. When the commissioner of health finds upon investigation that a public water supply is subject to the danger of contamination by reason of unsatisfactory location, protection, construction, operation, or maintenance of the system, or by reason of the existence of an unsafe

emergency supply or connection to an unsafe private or auxiliary supply, or if the commissioner of health finds upon investigation that the public health is endangered by reason of the existence of an inadequate public water supply or water-works system, he shall notify the city, village, county, public institution, corporation, partnership, or person owning or operating such public water supply or water-works system, of his findings and of the time and place, when and where a hearing may be had before the public health council. Such notice shall be by personal service, or shall be sent by registered letter to the mayor or managing officer or officers of the city, village, county, or public institution or to the corporation, partnership, or person owning or operating such supply. Investigations made in accordance with this section may be at the initiative of the commissioner of health.

SECTION 1252–5.

Section 5. After such hearing, if the public health council shall determine that improvements or changes are necessary and should be made, the commissioner of health shall notify the mayor or managing officer or officers of the city, village, county, or public institution or the corporation, partnership, or person owning or operating such water supply or water-works system to make improvements, corrections, and changes in the location, protection, construction, operation, or maintenance of the water supply or water-works system satisfactory to the commissioner of health, so as to prevent the contamination of the water supply or to provide a water supply not subject to the danger of contamination, or to provide a water supply and water-works system adequate to avoid endangering the public health. The order of the commissioner of health and the time fixed for making the improvements or changes shall be approved by the public health council, and the notification shall be made by personal service upon or by registered letter to the mayor or managing officer or officers of the city, village, county, or public institution or the officials, corporation, partnership, or person to whom said order shall apply. When such order is issued subsequent procedures shall be in accordance with and governed by the provisions of sections 1257, 1258, 1258–1, 1258–2, 1258–3, 1258–4, 1258–5, 1258–6, 1258–7, 1258–8, 1259, 1259–1, 1260 and 1261 of the General Code.

A portion of the sections referred to in Section 1252–5 provides for a rather elaborate form of appeal from the state department's orders, in which outside sanitary engineers are appointed both by the State Department of Health and the appellant, and these engineers may, if necessary, choose a third. The State Department of Health must finance its part of the expenses equally with the appellant. These engineers have the power to change the department's order, and the supreme court has final authority on a petition of error. It would appear that the right of appeal to the courts for modification or revocation of any order by the State Department of Health would be a fair procedure and a much simpler one.

Section 1258–1 states that appeal may be made to the Public Utilities Commission for increased revenue to meet expenses for changes ordered by the State Department of Health, and requires that the commission provide for necessary financing. Sections 1259 and 1259–1 provide for

procedure by which a municipality shall obtain necessary revenue for complying with the orders issued, and Section 1260 makes municipal officials personally liable for non-compliance with the procedure.

Some such statutory procedure is needed if mandatory powers are granted, because it is of little avail to grant statutory power and allow local officials to hold up their hands against the enforcement of a necessary order and say, "No funds in the treasury."

Manure contamination of a water supply in large amounts may cause trouble. It is certainly always objectionable on aesthetic grounds, and it interferes with bacteriological control of a water supply. There seems to be no reason for specifically exempting it by legislative enactment. Manure contamination in the ordinary process of land cultivation cannot be rightfully excluded by rules and regulations. The property owner should always have the right of appeal against property damage, and cases may arise where it might be advisable under certain conditions to order the purchase of heavily manured land on the shore of a reservoir.

Bathing in drinking-water supplies is now prohibited by statute in five New England States, and limited in the remaining State. It is a known fact that promiscuous bathing does exist in tributary streams or ponds on some of the large supplies in even those States where it is legally prohibited. Local officials often wink at it, especially in cases where a watershed is very large.

The question is often raised as to whether or not, especially in cases of new water supplies, persons with summer homes or camps on tributary ponds or streams should receive any compensation for loss of bathing rights. The various state statutes do not recognize bathing as a prescriptive right, and forbid it under the police power. It seems necessary to have such legislation enacted under present New England conditions and subvert the interests of the few to the benefit of the many.

Boating and fishing in reservoirs can be prohibited in Massachusetts, New Hampshire, and Connecticut by local ordinance. No state regulations are in effect.

The Massachusetts statute, authorizing the Department of Public Health to make rules and regulations, specifically states that the Department may delegate the granting of permits to local authorities. There are unquestionably cases of fishing on tributary streams on large watersheds where the danger is at a minimum, and the general tendency has been to leave the matter to the discretion of authorities in each individual case. Where the shore line of reservoirs is entirely owned by a water company or town, the situation is simplified. The dangers from boating and fishing on reservoirs have been thoroughly discussed in an excellent paper by Mr. X. H. Goodnough, read before this Association. Boating and fishing in reservoirs are a health menace and should certainly be prohibited on direct, unfiltered sources of supply.

The procedure provided for by Chapter 111, Section 160, of the Laws

of Massachusetts, placing the granting of permits at the discretion of the Department of Public Health or its delegated representatives through rules and regulations, apparently has worked out satisfactorily.

There should be statutory authority to take land for watershed protection by right of eminent domain. Either approval by the superior court, as in Connecticut, or by the State Department of Health, as in Massachusetts, should be stipulated. Some method of equitable settlement must be provided.

The Connecticut statute requiring superior court approval for a reservoir within a half-mile of a cemetery, should be amended. The public health hazard of a cemetery close to a reservoir is probably not great, but at least aesthetic considerations warrant some statutory regulation. The Massachusetts statute prohibits new cemeteries on watersheds, without state approval, and seems desirable. As the State Department of Health should pass on new sources of water supply, new reservoirs and existing cemeteries are thus covered.

The question of cross-connections between public water supplies and auxiliary impure supplies for fire, industrial, or other purposes is claiming increased attention of water-works men because of continual disease outbreaks from such connections. New Hampshire has passed a statute on the subject, which has already been mentioned. Connecticut has recently followed the lead of New York State in incorporating cross-connection regulations in its sanitary code. Either the latter procedure or statutory authority to state departments of health which have no sanitary code, so that necessary regulations can be adopted, should exist. The New Hampshire law practically admits the installation of valves. The manner of cross-connections had better be left to the discretion of the State Department of Health who are in a position to determine the efficiency of various methods.

Massachusetts and New Hampshire have special legislation for emergency supplies. While the approval of the State Department of Health should be necessary under its other statutory powers providing for approval of all supplies, yet the Massachusetts procedure which sets up the machinery for cities and towns to act in emergency is worthy of consideration.

Summary.

This review of some of the outstanding features of our New England state laws and regulations pertaining to public water supplies is offered for the purpose of at least awakening thought upon the conditions in our various States. Certainly the laws of some of our States need revision, and there is no body of men better prepared or more vitally concerned than the members of our Association. It may be possible to do some work with poor tools, but sharp tools, in the shape of clear-cut laws and regulations, are preferable.

The amount of mandatory power granted to state departments of health will always vary, according to local conditions and traditions, but

it is important that mandatory power be coupled with clear laws and adequate personnel for enforcement. In the language of the late George C. Whipple, "If state departments of health issue orders, they must be prepared to enforce them. Every order disregarded stands as a tribute to degenerate government. Is not authority without power futile?"

DISCUSSION.

ARTHUR H. PRATT.* The provision by statute of restrictions on waters tributary to a reservoir are very helpful to water-works men. If these restrictions are too great, however, with the modern means of transportation and the tendency of the times towards the development of small ponds and building lots, it may become troublesome to those who are developing new supplies. I think most of us have generally had the thought that whatever restrictions had to be placed on an owner, whatever expense he had to be placed to where a new supply came into the field, perhaps the new supply ought to pay the bill. After the works are built and the new owner comes into the field, he, knowing the conditions, ought to pay the bill. In other words, the person on the ground has the prior right.

In the condemnation of lands in connection with the building of the Wanaque Works we have found a situation which brings up the question whether or not too much statutory prescription is a disadvantage. We had a situation there of one very large owner of about 35 000 acres of land, 10 per cent. of which we are taking. In trying the case before a condemnation commission the owner claimed damages for his residue, which, I suppose, is strictly in accordance with condemnation procedure; and one of the real-estate experts, who testified for him, testified to a damage of $10 per acre for the residue, due to the fact that the simple provisions mentioned here today would be enforced on the owner. Certainly any such bill as that against the project is a rather large bill to pay, and perhaps it would be better if we did not have such a statute than to have to pay such a bill.

The areas tributary to the Wanaque project are developing in the way of small pond real-estate operations very rapidly. I think there are something like sixteen small new summer developments being created on the various tributaries now. The real-estate man seems to think there is no limit to the number of bungalows which can be sold in such areas. He thinks he can sell if there is water, but the person who buys that kind of property wants to bathe in that water, he wants to boat on it, but is not content to live near it and see it. Of course if the water area is large enough and the ratio of volume to the bathing is great enough, and it is some distance from the reservoir, there is no valid sanitary objection to the practice. But there must be a limit. In the Wanaque watershed there is a large lake, and while there is some bathing there, an examination of the water over a period of years indicates that it is not materially influencing the quality of the water as it flows out of the lake.

There are two sides to this question.

*Chief Engineer, North Jersey District Water Supply Commission.

ROBERT SPURR WESTON.* Mr. Scott is to be commended for getting this material together in such an admirable way.

There is something to be said in favor of the Ohio method of referring purely technical matters on appeal to a Board of Engineers to determine the facts, rather than to a master appointed by the Court for the same purpose. In two cases with which our firm has been connected recently it has been extremely difficult to get a master having a very fine mind, but a very fine legal mind, to understand matters involving the kindergarten principles of mechanics and physics — to say nothing of sanitary science. I am sure that is the fundamental reason for the Ohio law. There is a great deal to be said in favor of a sanitary engineering Board of Appeal rather than the Court.

MR. SCOTT. I think there is perhaps much to be said in favor of what Mr. Weston speaks of. The only feature of the Ohio statute that does not appeal to me is that half the expenses must be borne by the State Department of Health. If the State Department of Health was short on appropriations and very many of these investigations came up, the department would be somewhat handicapped in pushing matters to a head before a commission of engineers, if it necessitated the burden of half the expense every time such cases arose. If a scheme could be worked out whereby the State Department of Health would not have to take the money out of their appropriations each time a hearing was necessary, I think that Mr. Weston's scheme would be preferable to hearings before the Court.

STEPHEN H. TAYLOR.† There is one matter which I think should be discussed, and that is of the cross-connection to polluted supplies. I see we have with us today quite a number of our insurance friends, and I think it would be well to have a thorough discussion of this feature at this time.

As we all, or probably most of us, know, the American Association has gone on record as unalterably opposed to cross-connections to polluted supplies. At the meeting at Buffalo I was very lonesome in my stand that cross-connections might be permitted, provided proper check valves were put on to prevent the polluted supply from entering the mains and — get this particularly — proper inspection made of those check valves. You can put on all the check valves in the world, but if you do not attend to them and inspect them frequently they are useless. But in New Bedford we have some sixty-odd sets of double-check valves in service and we make it a business to inspect and test them at least three or four times a year and if they show any sign of weakness of course we remedy the trouble. The rubber facings should be renewed as often as necessary. We have never yet found any set of these check valves which was not operating effectively. If one leaked a little the other one held, so that no set of double checks has been defective. Of course we know that one of the duties of the water system is to furnish fire protection to its inhabitants, and perhaps especially

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†Superintendent, Water Works, New Bedford, Mass.

to the large manufacturing concerns where these supplies are needed. I think the point is well taken by the author of the paper that this should be subject to regulation and I believe that an inspection of these check valves would permit of their use with safety to the system. At the American Convention I was very much in the minority when I made that statement, but I think it is so.

CHARLES W. SHERMAN.* The fault I have to find with Mr. Taylor's statement is, that a perfect inspection means an inspector on the job all the time, or some kind of a tell-tale with a perfectly operating electrical or mechanical means which will signal to the water-works office, or to some responsible party, in case any leak does occur.

Mr. Taylor speaks of inspections three or four times a year, which in his case seem to have been entirely satisfactory, since they have always found at least one of the checks all right, and no leak has occurred. It is of course entirely possible that on the very day, or even ten minutes after an inspection, something might occur that would start a leak through both checks; and if the next inspection did not occur for three or four months, very serious trouble might occur in the meantime.

I do not say that in criticism of Mr. Taylor's stand. I have myself given qualified approval of double checks in one or two cases, and I think they have a place; but as a rule I would rather have an absolute physical disconnection of the systems, if possible. I think that is the ideal towards which we should work, and that such installation should be permitted only when conditions are distinctly favorable for them, and when there is no interference from political or other sources which might make inspection a mere matter of form, and when the responsible authority can have ample control in every way of the installation and of its working.

HARRY A. BURNHAM.† I am very glad to supplement Mr. Taylor's remarks. He has given his limited experience in the installations at New Bedford. The Engineering Department of the Mutual Companies has had a wider experience than that,— an experience with over a thousand such installations,— and in the long period of years in which we have been observing these, we have had the same experience regarding what might be called double leakages; that is, leakage of both checks under test with ordinary conditions of maintenance. We have not found any such. And with the improved inspections which are still possible, I would be very sure that we will not find any in the future.

W. L. HATCH.‡ This question of cross-connections is really a very serious thing in Connecticut. We have been given notice that all of them must be discontinued; cross-connections must be done away with by the first of January. Now, in New Britain we have perhaps in the neighborhood of forty cross-connections among four or five of our manufacturing plants. I would very much like to hear what some of the insurance men

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‡Water Commissioner, New Britain, Conn.

have to say about the practicability of doing away with all of these cross-connections and still getting satisfactory fire protection and water supply for sprinklers and standpipes.

C. W. MOWRY.* Mr. Burnham and I are both from the Factory Mutual Fire Insurance Companies, which began to recommend the double-check valves about eighteen years ago.

Mr. Scott spoke of the chances of disease from bathing, fishing, eating shellfish, and pollution of watersheds in general. Our position is that there is just as much chance of disease from these sources, perhaps more so, than when the double-check valves are carefully installed and properly maintained. So far as I can learn, after the eighteen years' experience, there has been no case of a public water supply having been polluted through a set of double-check valves. The facts are that there is no pressure in the yard system higher than that of the city system, except when the fire pump is running at time of fire or at time of pump test, and that is only occasionally; so that even if under the conditions of the test you should find two checks leaking, as in the isolated cases mentioned, even at that time there would be no flow from the yard system out into the street main, because the city gate valve is closed during a pump test; and at other times the yard system contains only city water.

The gentleman asked about the provision for water supply in case the double-check valves had to be discontinued. The public water supplies of so many of our New England communities are so excellent that it would be a practical impossibility for a manufacturer to furnish anything that would duplicate them in capacity and in reliability. The effective use of public water through automatic sprinklers has prevented many serious fire losses and saved many lives.

Mr. Taylor speaks of Massachusetts. That is probably one of our oldest industrial centers,— with large manufacturing cities like New Bedford, Fall River, and Lawrence. There for years the double-check valves have been in use, and the recent report of the Department of Public Health of Massachusetts states that the typhoid rate is constantly decreasing, and they expect that if it continues to decrease at the same rate, it will be only a question of a few years when it will be entirely eliminated. Massachusetts seems to be satisfied with this arrangement of protecting public water by means of double checks.

Whereas it may be possible in some cases to provide a water supply which will be the equivalent of a city supply for a small risk, yet there are many manufacturers who have a large concentration of wealth in a single plant which has been built up gradually because the automatic sprinkler has provided the means of protecting that plant. They have developed and grown because they have had a large water supply from the city upon which to depend; and now to have that suddenly taken away and to be required to provide a substitute is going to represent in the aggregate a

*Factory Mutual Fire Insurance Companies, Boston, Mass.

vast expenditure of money. Such an outlay for a needless duplication would not only be an economic waste at a time when our New England industries can ill afford it, but — what is more important — the fire protection would in many cases be seriously weakened.

I believe that if the double-check valve receives the coöperation of manufacturers and public water officials, and if both work together to keep these valves clean, and tested as frequently as necesary,— just as we have done with boilers in many States,— the problem can be worked out to the satisfaction of all concerned. Every plant which contains a boiler has a potential life hazard, and yet we do not say that the boiler must be separated so far from the plant that if it blows up it will not injure anybody. That boiler is inspected regularly and periodically by the boiler insurance companies and a certificate of inspection is filed with the Department of Labor in the State House. That has worked successfully for many years and no one questions those inspections.

Now, I feel that a system of inspection could be worked out, — is being worked out, as Mr. Taylor has done in New Bedford, and that these check valves can be maintained so that the chance of danger from them is far less than it is from many other sources, such as bathing and shellfish pollution, and other dangers of that sort.

Mr. Hatch. In case a large plant has two sources of supply, the private supply and a public supply, could a connection to the public supply from different streets be arranged so that at no time would there be a prospect of both being shut off for any reason, to take the place of the public and private supply with the sprinkler equipment, and so forth?

Mr. Mowry. I assume that question was directed to me. For fire-protection work we depend upon the automatic sprinkler because it is on the job day and night, and when the fire comes it opens instantly. Hence it ought to have the water supply all the time, constantly. In some cases a plant can depend upon the public water supply most of the time, but to care for those occasions when the public water is off, or to supplement it when it is not adequate in amount, we have found that the secondary supply was desirable. A public water supply giving four hundred or five hundred gallons a minute will care for twenty or thirty sprinklers, but if a flash fire occurs, it opens a larger number of sprinklers than that, which overtaxes the public water supply, and it is necessary to supplement that by some secondary source. Oftentimes, too, the opening of many sprinklers will lower the water pressure to a point where it will be inefficient for distribution. The fire pump can raise the pressure to 80, 90 or 100 pounds and maintain that pressure. For these reasons our experience has shown that the secondary supply is the needed factor of safety, if we are going to assure the effective operation of the sprinkler system at all times.

Mr. Hatch. Is it possible to get that without that physical connection?

Mr. Mowry. There are ways which have been suggested for doing

it. If the fire pump were equipped with a reservoir of sufficient capacity, and that reservoir were fed with city water and the reservoir were built above ground with a closed top in such a way that no drainage or other impurities could find their way into it, that would not be a physical connection as I understand it is being interpreted. But if a plant has a river or a pond from which to draw, the cost of providing a reservoir of unlimited capacity to replace that river or pond would in some cases be prohibitive. Otherwise, the fire protection would be materially lessened.

Another thing that has been suggested is to provide a large elevated tank and to carry the water up to that elevated tank in such a way that the water from the city would feed into the tank above the water level and then flow from the tank into the sprinklers. Of course that does not give the full, unlimited capacity that the street main would, and it involves a rather expensive structure for a large tank, but in certain cases it could be worked out. It would be nothing like, however, a direct connection. It would be a high price to pay.

PERCY R. SANDERS.* I think it would be rather interesting to know from the records of the Insurance Companies how many times in these fires these auxiliary supplies have been used.

MR. MOWRY. I have not the records with me, but from my experience, which covers about twenty years, I can say it is the practice in some plants to start the fire pump immediately upon the sounding of an alarm, with the idea of boosting the pressure for hose streams and for sprinklers and thus jump on the fire quickly. They start the fire pump almost every time they have a fire of any size, whether they actually are going to need the pump or not, with the same idea that when you ring the public fire alarm, five or six pieces of apparatus respond — not that you are going to use all those pieces or will need them, but they are there in case you do need them. That is the way the fire pumps of a manufacturing plant are used; they are started and raise the pressure, and there are many cases on record where the secondary supply has saved the day, because it provided a greater capacity and pressure than the city water was able to furnish.

MR. TAYLOR. I think I am safe in saying that in New Bedford when a very small fire occurs, the sprinkler system is wholly from the city. I recall one very large fire in New Bedford which burned the two upper floors of quite a large mill, due to the sprinklers being shut off at the start of the fire. I went into the yard, and although they had four or five fire pumps on the property, only one small one was running. We usually give them a connection from two separate streets or from two sections in the same street. We put valves on both sides of a private connection so that often the chance of its being shut off is very remote. I do not think there is one time in one hundred in New Bedford that the fire pumps are started for the small fires.

C. DWIGHT SHARPE.† It seems to me that there is another side to this

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†Superintendent, Water Department, Putnam, Conn.

question that has not been touched upon yet. That is the manufacturers' side. In many places, in the small towns, the manufacturing interest is very large, and we ought, in a way, to practice the Golden Rule in dealing with these mills. If I had my way there would be no cross-connections, but I would like to have spread upon the records of this Convention the other side of the question.

How much elevation is it necessary to have from a tank to supply sprinklers? Now, these insurance men have many places, out in the country, where there is no city water and the factories have their own tanks. What do the insurance men require of the manufacturers in capacity of the tanks to supply a certain number of sprinklers? They must have some rule in regard to it, and it seems to me that it would be of very much interest to the superintendents and managers of the water departments to have some sort of record on the proceedings of this Convention, as to what we have got to require of the manufacturers, if we take out their cross-connections, and the proportion of cost that they will have to pay.

WILLIAM A. MACKENZIE.* Another method of maintaining a reserve water supply for the sprinkler system, where the auxiliary polluted supply is disconnected from the municipal system in order not to install the double-check valves, is as follows:

Connect the auxiliary polluted supply with the reserve fire pump and pump into a separate pipe system for outside hydrants, to be located at advantageous points. Then install one or more expansion tanks of the required capacity, with a small electric motor and pump for the reserve or auxiliary sprinkler supply. This reserve supply would operate the sprinklers for the flash fire in case the city supply was shut off. With the ordinary factory, where not over two or three expansion tanks would be required, it seems to me to be a feasible and economical method of complying with the state law.

The plan has been proposed by a large factory to one of the Factory Mutual Insurance Companies and, if satisfactory to the Insurance Company, it will be installed, as it will cover all the requirements of the State.

M. N. BAKER.† This matter has come up in one form or another at a number of conventions. It has been under advisement by the State Sanitary Engineers Association, which is composed of the engineers of the State Boards and Departments of Health of the country, with representation also from the United States Public Health Service, and has had much study from that organization, which finally has adopted very strong resolutions against cross-connections.

A year ago the Fire Protection Division of the American Water Works Association adopted similar resolutions against the cross-connections. This year the matter was brought up before the full convention at Buffalo of the American Water Works Association and the action of the Fire Protection Division was endorsed.

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†Associate Editor, *Engineering News-Record*.

It seems to me that it is time for the New England Water Works Association to fall into line with the State Sanitary Engineers and with the American Water Works Association, and to take a very strong stand against cross-connections.

You all know of the work of the Fire Prevention Committee of the Fire Underwriters Association. The engineers of that body at the Buffalo meeting of the American Water Works Association unqualifiedly endorsed the movement for the abolition of cross-connections, and said that they would stand by any efforts that were being made for its abolition.

I wish it could be stated here in just how many States of the Union cross-connections are now unlawful. I think the number is considerable. In Minnesota, I think; New York, I know; and you have heard of the movement in Connecticut. In Buffalo the local Fire Underwriters have recently announced that hereafter no premium credits will be given for these auxiliary supplies, on the ground that they are unlawful because they have been prohibited by the State Department of Health.

When it comes to the double-check valve, what does it mean? If one check valve will at times fail and leak, will two do more than cut the menace in half? The menace of polluted water is so great that no chances should be taken. We should not rely, even if there are three or four inspections a year, upon those alone when we know that between inspections something may go wrong and we may have an outbreak of typhoid fever. Many of us here have witnessed those outbreaks in this country to a large extent disappear. That is to say, we have now cut down our typhoid to very low limits, as has been stated in regard to Massachusetts, for instance; and it is going lower. But there is an occasional outbreak, and I think that existing cross-connections with emergency supplies are dangerous things, and I hope to see at this Convention, or at a later one, the New England Water Works Association fall into line with the State Sanitary Engineers and the American Water Works Association.

CALEB M. SAVILLE.* Mr. President, I think perhaps the gentlemen here know that I am one of the original promoters of the abolition of the double-check valve and usually speak on it when I have an opportunity. I do not object to that burden at all.

I agree with Mr. Sherman, Mr. Gage, and Mr. Baker. I think that some action should be taken. I am not sure, however, whether that action should be taken by a vote at a meeting of a convention such as this. I think more or less snap judgment is apt to come in if considered now.

I would suggest, and I would make the motion, that the Chair appoint a committee of this Association to consider this matter and bring it before the Convention, or at a later meeting of this Association, which it will probably hold during the winter sometime, for a report at that time. Then possibly, as this is an important matter, it could be taken up by letter

*Manager and Chief Engineer, Board of Water Commissioners, Hartford, Conn.

ballot after that report had been submitted. I do not know about that; that might be a matter for judgment later.

Hartford, as you know, is one of the principal insurance cities of the country. Probably there are more of the larger fire insurance companies there than in any other city of the country. Hartford has absolutely abolished the double-check valve, — physically separated its system from any other. There is no connection, so far as we know, between any other source of water supply and that of the city in Hartford.

It is interesting to note — now, I am saying this very carefully, and I am not at all casting any aspersions in any way, but of all the fire insurance companies in this country that have risks, I think the Boston section of the Factory Mutuals is the only one which expressly objects to the abolition of the double-check valve system. Mr. George W. Booth of the National Fire Underwriters has gone on record as to what his opinion is. I do not know that I quote him correctly, but the substance of his remarks was that "The National Board of Fire Underwriters does not advocate the use of double-check valves connecting a polluted source with a public supply; in fact, they are against it so far as they can be. If, however, there is such a connection existing, they cannot fail to give credit to that connection as a source of protection." I think that is in general their position.

Now, the fact that there are other polluting sources, such as shellfish, bathing, and so forth, seems to me is really no argument for taking on another polluted source. We might say that we could have all kinds of things. Because we cannot thoroughly enforce the law on prohibition, or we do not enforce it, is no reason for saying that we should not enforce it against stealing or something else. We should try to do everything that we can for good government.

Are you recognizing the fact of the expense that it will be to many manufacturing plants to get proper fire service? That is a thing, I think, that they should pay for. They get the protection. But I also think it is a thing that the towns or cities should pay for also; I think they should come in. In Hartford, for instance, when the double-check valves were taken out the city of Hartford increased the size of its mains, they put in additional hydrants, they put in additional valves, and did all that they could to bring the system up to a point where it would give adequate protection to the city. On the other hand, the manufacturers — good citizens, every one of them — went to considerable expense. A gentleman who has spoken mentioned the fact of millions of dollars being involved. We have millions of dollars involved in Hartford. The Underwood Typewriter Company, for instance, had, I don't know how many millions of dollars involved. They have put in a very large and elaborate plant at the suggestion, I think, of Mr. Burnham. Isn't that right, Mr. Burnham?

Mr. Burnham. Yes.

Mr. Saville. There was coöperation between the city and its good citizens, who were citizens as well as manufacturers.

One gentleman has asked about the pressure that is required for sprinkler heads. Mr. Burnham will correct me if I am wrong, but I have understood that ten to fifteen pounds on the highest sprinkler portion of the building was sufficient for fire protection. Of course that is on the basis of having an adequate amount of water for those sprinkler heads.

Then there is another thing. Of course it is well known that if a sprinkler system does not put out a fire at the very inception of that fire it is of no particular value. The first 15 minutes is the time, as I understand it, when the sprinkler system is of service. After a fire has got well under way, is burning fiercely and your walls begin to fall in, we all know that the breaking of these large-size sprinkler pipes is apt to bleed your system and not only be a detriment to your fire protection on that particular building but also to surrounding territory.

We are very careful to chlorinate our water; we are very careful to filter it. The meetings of this Convention here will be, almost for a half day, devoted to considering means of sterilizing water and giving safe water to consumers. We do that at the source. We do everything at that point to make a safe water for the people. Then we come in and allow a potential source of pollution right in the center of our city where we have not the vision to predict the result. It is not always typhoid fever. I do not think that the fact that we have never had a death from a leakage of this kind is a criterion to go by. If you have a leakage from a polluted source, even if there are not typhoid germs or bacteria in the water, there is a condition of the water that may produce some other sickness. It is not necessary to kill anybody in order to prove that you have got a bad condition. The city of Albany has a judgment against it (*Engineering News-Rec.* Nov. 25, 1926, p. 889) for $3 000 for damages on account of typhoid fever from its polluted water supply, and 13 other suits have been filed. With this record, is it good judgment to allow a known possible source of contamination to remain because, forsooth, some insurance company may have to take on a little more risk or a manufacturing plant save a little more money to apply to its dividends for stockholders who may or may not be citizens of the city?

MR. SHERMAN. I would like to second Mr. Saville's motion. He has expressed admirably what was in my mind when I refused to make a definite motion a little while ago. I do think this matter is of too great importance to be passed upon at a meeting of a convention containing only a part of the members of the Association, and where no notice was given in advance that this very important subject was to be voted upon.

There is just one matter that occurs to me that I think perhaps might be advantageous, and I will ask Mr. Saville if he thinks it is worth while to accept it as a modification of his motion — if not, my second will stand to the motion as he has offered it. What I have in mind is that the President should appoint a committee after an executive committee meeting, after the matter has been discussed, in order that he may get the advice of the

Executive Committee on not only the personnel of the committee but the method in which the Association should receive and act on the report of the committee when it comes in.

MR. SAVILLE. I should be very glad, Mr. President, to have that incorporated in what I made as a motion.

(The motion made by Mr. Saville, as amended and seconded by Mr. Sherman, was carried.)

LININGS AND COVERING FOR WATER PIPES.

BY BENJAMIN TALBOT.*

[*Read September 14, 1926, by John L. W. Birkinbine.*]

The enormous wastage which occurs to pipes from corrosion has been realized by water engineers throughout the world for many years, and many methods have been adopted, and a vast amount of research work carried out, with a view to reducing this continuous expense. Instances have occurred of cast-iron pipes remaining in service in satisfactory condition for very long periods, such as at Versailles where pipes installed over 250 years ago are still in use; unfortunately for those responsible for supplying large cities with water, such cases are rare. In many cases it is necessary for the pipes to be periodically scraped out, thus incurring additional expense. The case of mild steel pipes is worse; the great advantages of steel over cast iron, such as lightness, flexibility, and saving in laying costs, are quite outweighed by the rapid corrosion liable to occur with their use, and numerous well-known examples have occurred where maintenance charges of steel mains have become so severe, after a few years' service, that they have ultimately been discarded. The lighter section of steel, coupled with the fact that corrosion of mild steel is under most conditions far more rapid than that of cast iron, has proved in practice that the life of such mains, protected by the usual well-known methods, is comparatively short. Another serious drawback to the efficiency of ordinary water mains is that with many waters heavy encrustation occurs on the walls of the pipes, reducing their effective diameter very rapidly, and in the case of small pipes rendering them entirely useless after a few years' service. This difficulty is met by frequent scraping of the mains, or ultimate renewal. Such methods are clearly the result of failure to cope with this difficulty by any better method, and entail heavy annual expense in all such cases.

Most of the various methods employed in the past for preservation of such pipes have been based on various coal-tar pitch solutions applied hot to the pipe surfaces. The surface so obtained is quite satisfactory, from a corrosion-resisting point of view, for a few years, but tar products are by no means stable, and after a comparatively short period the surface no longer is capable of resisting corrosive attacks owing to the decomposition of the tar coating. With reference to adhesive growths, one essential factor in preventing these is that the surface of the pipe be as smooth as possible in order that there be no point to which the material can first attach itself; with such tar-dipped surfaces the coating is so thin that the uneven surfaces of the casting are not leveled off, but merely follow the

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contour of the pipe surface, and as such, even while the tar remains in good condition, the liability for growths to adhere is not greatly reduced by the process of tar-dipping. Bitumen dips are far better than those prepared from tar bases, but owing to their greater cost have not found great favor among cast-iron pipe-users. For steel pipes, however, where corrosion is even more serious than in cast iron, bitumen-dipping is resorted to; bitumen has very lasting properties and, if properly selected, will resist corrosive attack indefinitely. The drawback in using it for dipping purposes is the possibility of some portion getting scraped or chipped from the pipe surface, leaving a portion unprotected. For external protection one of the methods employed for steel pipes is that of wrapping the dipped surface with one or two layers of bitumen-soaked Hessian cloth; this frequently gets damaged in handling, exposing the metal, and also in many cases the cloth fails to become entirely impregnated with the hot bitumen, in which case it soon rots away, leaving the metal unprotected at those points. Attempts have been made to use a thicker coating of pure bitumen, but the excessive cost of this — coupled with the fact that such bitumen coatings when used alone, if sufficiently hard to be satisfactory from a flowing point of view, are liable to chip and flake in a marked degree — have rendered such attempts abortive.

During the last few years an entirely new development for the prevention of internal corrosion has arisen,— that of concrete lining of pipes, generally by centrifugal means. Such methods certainly are a great advance over previous ideas, and have successfully overcome many difficulties met with in the older methods. Concrete linings may vary in thickness very considerably from a mere cement-wash up to linings of considerable thickness for large-diameter pipes. There are, however, one or two drawbacks to this process, which may be enumerated as follows:

1. Concrete is not entirely impervious to water, and with the linings of lesser thickness there is a possibility that corrosion will eventually be set up. A characteristic of centrifugal concrete linings is that the surface is liable to fine hair cracks on maturing. These hair cracks, though possibly not serious in themselves, may form a lodgment for growths.
2. The extra weight entailed by the concrete lining is considerable, especially in the case of the thicker linings for large-diameter pipes.
3. The application of concrete as an external protection, by the method of bedding the pipes in concrete, is very expensive.

Corrosion has been the subject of many years of research, and a great number of theories have from time to time been put forward. No single explanation has so far been considered to have completely satisfied all the points arising, and it is not the purpose of this paper to enter into this question. There are, however, certain facts which have been definitely established as having a direct bearing on this subject, and provided a means of preventing certain agents from coming into contact with the metal, the exact method in which they promote corrosion is of no concern.

It will be agreed that corrosion may be brought about by: (*a*) direct oxidation of the metal by moist air, carbon dioxide, and air dissolved in water, or other similar conditions; (*b*) by direct chemical solution, *i.e.*, by chemicals present in the water capable of slowly dissolving the metal; (*c*) by electrolytic action. This involves the presence of an electrolyte in contact with the metal.

When these three essential causes of corrosion are considered, it will be realized that all three are rendered innocuous if the metal can be completely sealed off from the water by a material which will not be attacked chemically by any of the chemicals liable to be present in the water, and which will not disintegrate after the lapse of some years of service. If this material be also a non-conductor of electricity, the third source of danger will be doubly safeguarded.

To obviate encrustation, the internal surface of the pipes should be of such smoothness that there is no opportunity for these deposits to form a point of attachment, in the first place. Once a deposit occurs at points on the pipes there will form nuclei for the further growth of more material, until eventually a thick deposit will be formed on the pipe surface.

In view of the above considerations the ideal method of protection must have the following properties:

1. It must form an adhesive coating not liable to chip or crack, which is entirely impervious to water so that the metal is effectually sealed off from the water passing along.
2. The material must be entirely unattacked by any such chemicals as are liable to be contained in the water to be conveyed or, if applied for external protection to any solutions, liable to be generated from the surrounding soil.
3. The material should be a non-conductor of electrolytic corrosion and preserve the pipes, if protected externally, from electrolytic attack set up from stray electrical currents occurring, due to leakage from electric mains.
4. The internal surface of the finished pipe must be of such smoothness that no opportunity is given for foreign matter to adhere.

In addition to these, there are certain other properties which the material must have in order to make it serviceable for pipe mains.

1. It must not give any taste to the water.
2. It must be as light as possible to keep down freightage and handling costs.
3. It must not be affected by such variations of temperature as are met with either during laying or while on the track.
4. It must be tough and elastic so as to withstand reasonable handling without damage; this is more essential in the case of steel pipes, which in many cases distort by their own weight.
5. The cost of the process must be such that the benefits derived therefrom make the proposition one possible of consideration by water engineers.

The problem of pipe corrosion has been the subject of research along the lines indicated, for many years, and has now resulted in a new process

which is being introduced in this country by the Talbot Non-Corrosive Linings Company. It is known as the Talbot Hydro-Carbon Process, and has been found to completely fulfill all the requirements enumerated above. The process consists in applying by centrifugal force a bituminous composition so that a lining of any desired thickness is obtained. For most purposes a lining of $\frac{1}{4}$ in. in thickness is considered most satisfactory.

This composition is prepared by intimately mixing a finely ground inert filler with specially selected bitumen. The essential feature of the filler is that it be reduced to a fine-ground powder, chemically inert as far as possible, and which will not in any way react with the bitumen, such as:

Siliceous material: { Ground Granite, / Acid Open-Hearth Slag.

Aluminous material: { Slate Dust, / Shale, / Dry Clay,—

or Barytes,

or Limestone,—

consistent with its being sufficiently hard to withstand tropical temperatures, and the finished lining will not deform at temperatures up to 170° Fahr., when maintained for at least 24 hours at this temperature, nor is the lining brittle when similarly subjected to freezing conditions.

To insure the best results the interior of the pipes should be perfectly dry and clean before applying the lining material. The speed of rotation and temperatures can be so regulated that under centrifugal force sufficient bitumen may be exuded to the surface as to give a skin of comparatively pure bitumen behind which is a tough elastic body of lining material entirely inert to such chemical action as is liable to be met with in water supplied. The function of the filler is that it not only enables a reasonable thickness of lining to be applied, thereby covering and leveling off all the inequalities of the metal surface, but also overcomes the liability for the bitumen to chip off or flake, as the filled composition is of a tough, rubber-like nature which will withstand the usual methods of handling without being in any way damaged.

Long-sustained chemical tests have been carried out on the material, and it has been found that there is no reaction whatever with common acids, either organic or inorganic, in concentration up to 33 per cent.; and solutions of alkalis, both concentrated and otherwise, do not affect it in any way. Pipes have been tested in metallurgical works where electrolytic corrosion is one of the most serious troubles, and have been found to give most excellent results. Other pipes have been installed in conjunction with ordinary dipped pipes, for the conveyance of water noted for giving excessive encrustation, and were found to be free from all signs of growth, whereas the pipes protected in the ordinary manner were heavily encrusted,

thereby indicating that the extraordinarily smooth surface obtained gives no foothold for the initial attachment for such adhesion. This will immediately appeal to water engineers, as it will enable them to reduce the allowance for subsequent losses in diameter in the main and thereby make the adoption of smaller-diameter pipes possible for the same supply. A continuous internal lining can be obtained, eliminating surging at the joints and ensuring complete protection of the pipes at all points of the main. In the case of large pipes, the jointing is done from inside when the lining material, heated until it is in a plastic condition, can be rammed into the intervening space between consecutive linings and united together by means of a blow lamp. In smaller pipes a ring of the material, softened by a suitable solvent, is placed in the bell of the preceding pipe and the next pushed home. Excess of the plastic material is then removed by a long scraper; the solvent rapidly evaporates, leaving behind in the joint the pure hydro-carbon material. A further advantage is that of the reduction in the resistance to the flow of water, as it is believed that a considerable reduction in the main diameter is possible in most cases for equal discharge of water. Tests demonstrate a reduction of frictional resistance up to 10 per cent.

The Talbot Hydro-Carbon material can be applied by pressure for external protection of pipes, insuring an excellent means of preservation. This is more essential in the case of steel pipes, and by applying it to pipes with an externally patterned or serrated surface eminently satisfactory results are obtained.

Pipes lined by the new process have been installed by many of the leading water boards in Great Britain, and in view of the widespread interest which has arisen in that country over the process, it would certainly appear to be one worthy of the fullest consideration, as the process seems to be one which goes far to solve the corrosion and encrustation troubles encountered by water engineers.

Discussion.

President Bristol. I am sure Mr. Birkinbine will be very glad to answer questions.

Mr. Birkinbine. I have been making some tests in Philadelphia, using a very dilute sulphuric acid, similar to that from the storage battery room.

The untreated pipes would not stand 3 per cent. sulphuric acid. They would stand 10 or 15 per cent., but with 3 per cent. the material broke down rapidly, while the Talbot lining showed no sign of corrosion. Of course the material will not stand naphtha or benzine, or any of the solvents of the bitumen material.

The paper does not mention the mix which they have been using in England, which consists of about 62 per cent. of ground rock, the balance being asphaltic bitumen. At the present time I have some samples of the

lining which are being tested. One sample is being tested in the laboratory of a large paper company to see if it will handle sulphite water. Over in England they had trouble with a refinery waste that carried sulphate of copper and sulphate of iron, and there is no corrosion noted on Talbot lined pipe. I hope to send a sample of lined pipe out to Michigan where it will be tested out on some highly copperous mine waters.

I would like to add another thing that I did not call to your attention in the paper. I noticed it in the samples of pipe sent over from England. Where using bell and spigot pipe they are leaving a quarter inch or three-eighths inch of this material in the bell itself so that when the spigot of another length enters there is an insulating lining separating the two lengths of pipe.

I believe it is generally agreed now that electrolytic action is often caused by currents entering your main from service connections, and this lining being a poor conductor, the electrolytic action is practically confined to one length of pipe. Not having an opportunity to jump to the next length, there will not be the breaking down of the pipe around the joints.

A MEMBER. I would like to ask the speaker if this material has ever been used to line standpipes.

MR. BIRKINBINE. Not that I know of. I do not see any reason why it should not be, unless it be a standpipe of too great size. You see, the pipe is revolved on a horizontal axis, and it has to have sufficient speed to make the material cling to the surface by centrifugal force. They are now lining pipe in England up to 72 in. in diameter and 30 ft. long. But if you get into 10 or 12 ft. diameter, I am afraid the cost of machinery to do the lining would be too expensive, because it would require an elaborate machine and labor.

A MEMBER. I was wondering if it could be applied in any other way than by centrifugal action.

MR. BIRKINBINE. Oh yes, it could be moulded in, but you would not have the high gloss. The advantage of the centrifugal force is to get the high gloss which prevents tuberculation. Also, you could have the majority of the filler going to the wall of the pipe by merely varying the composition as it is put on.

A MEMBER. You never heard of its being done?

MR. BIRKINBINE. No, I have not.

A MEMBER. Do you know if this has been used on distribution systems at all? Can you drill through it all right without chipping it?

MR. BIRKINBINE. Yes.

A MEMBER. How would you drill the pipe? It would have to be a ratchet drill; you could not go through with a tapping machine, could you?

MR. BIRKINBINE. I think that will answer your question, sir (indicating pamphlet). The lined pipe can be tapped. It takes a good clean cut when it is tapped. The method of tapping, I should think, would be the usual process used for tapping cast-iron or steel pipe.

STEPHEN H. TAYLOR.* You say they line the inside of the bell with this material?

MR. BIRKINBINE. Yes, sir.

MR. TAYLOR. Will that take leadite? Will leadite make a good joint?

MR. BIRKINBINE. Unfortunately, I have been so long out of the water-works game — although I did start to be a hydraulic engineer and then went to the bad and got into mining — that I forget the term you use for the end of the bell of the pipe; but what I mean is, they put the dam that they use in the bell of the pipe, leaving a space of about a quarter of an inch between the end of the pipe proper, the true bore of the pipe, and the socket of the bell.

MR. TAYLOR. Then the gasket would fill that place?

MR. BIRKINBINE. Yes.

MR. TAYLOR. It would not come in contact with the leadite, I take it, from your description.

MR. BIRKINBINE. No, it could not.

MR. TAYLOR. Because there are about two inches of gasket there.

MR. BIRKINBINE. Yes, sir.

CHARLES W. SHERMAN.† I think it would be interesting if Mr. Birkinbine would speak a little bit on the external coating of steel pipe by this process. Obviously that cannot be applied by centrifugal force because it would throw it off rather than hold it on. When you consider the corrosion of the steel pipe from the soil, the external coating is of the utmost importance.

MR. BIRKINBINE. I am glad you brought that up. The external coating is put on the pipe simply by being fed on by a roller with considerable pressure against the pipe. I understand that the usual process they have been using over in England is, as soon as the pipe is thoroughly cleaned they dip it in a bitumen wash, both inside and out — just dip it so that it gets naturally coated inside and out; and then after that they heat the inside of the pipe as they apply the internal coating, and as soon as it has spun long enough to obtain a high gloss they spray the outside with water until it has set. Then when they come to putting on the external coat, the pipe revolves and the outside is heated, then the outer coating of the pipe is applied by pressure.

MR. SHERMAN. I was very much interested in the samples that Mr. Birkinbine had to show at the Buffalo convention. I have been enabled to supplement the information I got from him at that time by the experience of some British engineers during my recent trip to the other side. I do not wish to utilize too much of the ammunition that I expect to fire tomorrow, but perhaps it would be out of place not to say in connection with this discussion that I was especially interested to learn, in calling at

*Superintendent, Water Works, New Bedford, Mass.

†Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

the office of Sir Alexander Binnie, Son, & Deacon in London, that they are now using pipes of a considerable size coated in this way,— first, in a water system in Wales where, I understand, they were especially desirous of using steel pipes on account of the mine sediments, as they did not want to use cast iron, and they thought that this coating gave them sufficient protection to make a pipe comparable in durability with cast iron; second, in a water system that they have now under construction at Singapore. Mr. Morley, of that firm, who had just returned from Singapore, told me the pipes lying in the trench there at a temperature of 130°, showed no signs of the coating running — 130° seems pretty warm.

A MEMBER. I think there are two very important features which Mr. Birkinbine has not brought out yet. I think that most of us would be interested in hearing about these. First, just what coefficient or friction can be expected of this pipe; secondly, what does it cost?

MR. BIRKINBINE. Unfortunately, the information I got about the reduction of the coefficient of friction was very unsatisfactory, because an Englishman does not speak quite the same language as an American, and the information I got, as I read it, was that the friction was reduced 10 per cent.

Now about cost. Also this information I got by cable when I was at Buffalo was, that it would add about 7½ per cent. to the cost of a raw pipe. I assume that meant 7½ per cent. on an average, because it undoubtedly will add more than 7½ per cent. to a 4-in. steel pipe and it would add probably a great deal less than 7½ per cent. to a 72-in. cast-iron pipe. The cost seems to me to be a minor factor, possibly even if it was up to 12 or 15 per cent. In comparison with the cost, you would have the taking up and relaying of new pipes in their place, or the cleaning of mains or, in some cases, the total destruction of pipes and the necessity of purchasing and laying new ones.

MR. TAYLOR. As I understand, the lining does not go more than an inch from the pipe proper into the bell. Is that the idea?

MR. BIRKINBINE. Yes, about a quarter of an inch.

MR. TAYLOR. My point, Mr. President, was that if it went too far into the bell, would leadite adhere to it and make a good joint?

MR. BIRKINBINE (indicating on sketch). Here the pipe widens into the bell. A dam is placed about one-quarter or three-eighths of an inch from the end of the bore. The result is that the bore of the pipe is lengthened that much by the lining material.

MR. TAYLOR. And your gasket covers that part?

MR. BIRKINBINE. Yes, protects the lining against the hot lead. I do not think hot lead would do any great damage to the lining, although it might melt the lining and make a little rough surface.

MR. TAYLOR. You do not get my point yet. Lead may work all right, but leadite will not cling to iron unless it is very clean. It has to be pretty thoroughly cleaned before leadite will adhere. My thought was

that a substance like this probably would prevent the leadite from adhering to the iron. But as I get it now, it does not come in contact with this because the gasket covers it up.

MR. BIRKINBINE. Yes.

A MEMBER. I would like to ask the speaker if this process of theirs has ever been applied on genuine wrought-iron pipe.

MR. BIRKINBINE. I know that inquiry does not come from a representative of the wrought-iron pipe manufacturers, because all I ever heard from the manufacturers of wrought-iron pipe is that it lasts forever and does not need any coating. However, I see no reason for their applying it to wrought-iron pipe. I am not connected with the wrought-iron industry in any way, but see no reason for gilding the lily. Why should you go to the expense of buying wrought-iron pipe and then put a protective coating on it when you can protect as well the much cheaper steel pipe? Wrought-iron pipe is quite expensive. I know because I have to get quotations upon it every now and then in mining supply work. I know of no companies using this lining on wrought-iron pipe, and I should not think they would do so, on account of the greater expense of wrought-iron pipe.

ALBEUS P. MURRAY.* I would like to ask about the melting point. How much heat is required?

MR. BIRKINBINE. Do you mean to apply it, or to keep it from flowing? Mr. Talbot says it stands up to 170° Fahr. without flowing. It will not do to handle your hot boiler feed water; it would probably be distorted from that. But it would handle fluids at ordinary temperatures.

MR. MURRAY. Do you think the pouring of a lead joint would spread it enough to make it —

MR. BIRKINBINE. No, it should not injure it. Even in steel pipe, where you have a comparatively thin coat of metal, the lead cools so very rapidly that it has not a chance to bring the metal of the pipe up to a sufficient temperature to involve running into danger of injuring the lining.

A MEMBER. How long has the process been in use?

MR. BIRKINBINE. To the best of my knowledge, about two years. I know they have been making it for two years. It has been on the market about two years. How much longer I cannot say.

WILLIAM R. CONARD.† I would like to ask the gentleman, as to applying this material to the exterior surface,— whether it presents a glossy surface after they have finished. If he can answer that question, then I will go a little further in what I want to say.

MR. BIRKINBINE. I think it will lead me into trouble there. (I just want to say this: as a consulting engineer, a superintendent of construction once told me: "One of these many"— then he used an adjective; it was not "hydraulic," "steam," or "electrical"— in fact, it was not

*Superintendent of Meters, Providence, R. I.
†Of Conard & Busby, Burlington, N. J.

even civil — "engineers. They will try to improve everything. They will tell you how to run Heaven better, but they will never get a chance, for they won't be there.") So that I must say that I do not think you will get as high, glossy finish as you will in the interior. You will get the sort of finish that you see on the samples.

MR. CONARD. Of course you get the glossy interior, due to the fact that the heavier material, or the body of the material, tends to go outward, and hug the surface just the same as you will get in flowing concrete.

MR. BIRKINBINE. Exactly.

MR. CONARD. One gentleman asked concerning its application to standpipe work. My thought was to start from the bottom and build up on your standpipe, and that you might be able to get a floated surface, if the aggregate of your material was heavy enough, with the floating tool that you apply it with, to press the heavier material back. In standpipe work the necessity for obtaining the extremely smooth surface is not nearly so desirable as, of course, in the pipe line.

MR. BIRKINBINE. If you want a smooth surface, a blowtorch or a gas flame played against it will give a smooth surface, whether internal or external. Anything which will bring the bitumen to the melting point will give you a smooth, glossy finish. But in normal operation you do not get the finish that you would from a centrifugal force. As you look at this pipe you will notice the evenness of the coating. The people who saw the samples in Buffalo mentioned that fact. It was pointed out to me especially by a gentleman who was looking at it, and he was surprised to see how it kept up to gage. He noticed the practically even thickness around the pipe. It does not vary much anywhere. That would be perfectly natural if put on by centrifugal force, as you will find in the cement-lined pipes.

DAVID A. HEFFERNAN.* I would like to ask the speaker about cutting the pipe. Would you have to use some kind of an instrument to cut the lining?

MR. BIRKINBINE. Probably the best thing would be to use a hack saw, although you can cut it with a penknife. As you will see by the sample, the lining is so soft that you can pick it out with your finger nail. One of the samples that I had at Buffalo, used in constant demonstration, I would bang against a piece of 24-in. cast-iron pipe until I deformed the pipe considerably away from a true circle, and there was no breaking away. As I scratch it that way with my finger nail, you will notice it does not break absolutely clear, but there will be no trouble in cutting the coating. If you use an acetylene torch it naturally will melt your bitumen.

A MEMBER. In reference to tapping steel mains that have been coated by this process: it would seem to me that there would be some possibility of this material gumming in your tap. And then, furthermore, in these thin steel pipes, very frequently there are not a great many threads, and sad-

*Superintendent, Water Works, Milton, Mass.

dles are sometimes used. How would you work a saddle on a steel pipe? How would you get your thread to hold in the saddle and pass through your bituminous coating and also take hold at the correct pitch of the pipe itself?

MR. BIRKINBINE. I think in putting on a saddle you would probably remove your bituminous coating from the outside. I really could not answer that question, because I do not know. There is no use trying to bluff a bunch of water men, so I will say that I do not know.

I would like to say, Mr. President, that I greatly appreciate the interest that the Association has taken in this matter. It has been a great delight to me. In fact, I do not know when I have enjoyed anything in engineering as much as I have enjoyed my evening here in doing my best to answer the questions asked.

METHOD OF READING METERS, BILLING, AND COLLECTING REVENUE, PROVIDENCE, R. I.

BY ALBEUS P. MURRAY.*

[*Read September 14, 1926.*]

The city of Providence is about 97 per cent. metered, having nearly 40 000 meters varying in size from $\frac{5}{8}$ in. to 16 in., each meter being read four times a year. A few years ago the city was divided into four billing sections, to simplify the making of bills and the collecting of revenue. Previous to this time all yearly bills were due on the first of January each year, and it can readily be seen, with so many due on the same day, everything was hustle and confusion.

With the new system each section pays at intervals; namely, March, June, September, and December first, each section having about 10 000 consumers. This method is much easier for every one concerned.

Each section is divided into 25 districts or routes, assigned to nine meter inspectors, with one additional inspector to read scatterings, get special readings for change of ownership, and inspect all services opened for building purposes. Each route is included in a separate book of loose-leaf type capable of handling four years' readings. This gives the inspector the advantage of previous readings in locating large and excessive uses. When found he notifies the consumers by postal and suggests remedies to obviate leaks and faulty plumbing.

He also examines meters which are not registering, and looks for leaks, cloudy dials, and broken glass. These he immediately reports to the Meter Department who in turn bring the meters to the shop, where they are repaired and tested before resetting. As the city repairs all of the meters, the time a meter is out of service is of short duration, usually not more than a few days.

The meter system of Providence seems to give satisfaction, both to the city and to the metered consumers. The meters are the property of the consumers, who are obliged to purchase such as are approved by the Water Department. The city keeps all meters in repair without charge to the consumers, except in case of frost, abuse, or neglect.

Meters are set in cellars when possible, or as close as possible to the stopcock, which is located just inside the cellar wall. This permits the attachment of lateral pipes beyond the meter. Service pipes usually run into dwellings under the cellar floors, a small pit usually being provided in which the meter is set. The walls of these pits are generally built of brick, laid in cement, with natural earth bottoms so that any moisture that may get into them can leach out.

*Superintendent of Meters, Providence Water Works.

For the smaller sizes of meter their average dimensions are $2\frac{1}{2}$ ft. long by $1\frac{1}{4}$ ft. wide and from 1 ft. to $1\frac{1}{2}$ ft. deep.

Where service pipes enter the buildings above the cellar bottom the meters are usually located on shelves fastened to cellar walls, and are boxed up, unless the cellars are sufficiently heated to prevent the meters from freezing. The pits are built, and the shelves put up, usually, by the plumbers at the expense of the owners. It is always deemed advisable to set meters as low as convenient, in order that the water may be drained from them when it is shut off at the stopcock (the stopcocks having stop and waste). Meters are in some cases placed outside the cellar wall, where the house sets fifty feet or more from the street and where extra heavy lead pipe is not used.

In these pits also, brick walls are preferable, the natural earth being used for their bottoms, for reasons before mentioned. The average dimensions are about 3 ft. square and 5 ft. deep for the smaller-sized meters.

When reading a district for billing, the inspectors try to read every meter, but are allowed to turn in a book if all but 5 or 6 have been read. After all the books are in, there are generally a hundred or more meters left as scatterings. Each inspector makes a daily report of meters read, and of conditions out of the ordinary. Beside reading and inspecting meters the inspectors examine all annual rate supplies each year.

In cases where a bill averages one hundred dollars or more each year, the bill is sent quarterly; in all other cases, annually.

Each quarter in preparing for billing, the first step is to secure the meter readings from the inspectors, who start about two months ahead of the actual billing date, to read the meters. As the books are brought into the office they are sent to the billing room, paper clips first being put on each page where there are compound meters with double readings. In the billing, or machine, room there is a graphotype machine for making zinc plates for each account, the addressograph machine for printing the bill heads, and a specially designed Burroughs billing machine for printing the dates, the meter readings, and the subtractions showing consumption.

As each book is run off, it is returned to the Water Office with the corresponding bills, where clerks check off the readings in the book, comparing the book and the bills.

All bills are made in three parts,— a notice of the bill, which is a duplicate bill; the bill itself, which is the consumer's receipt, when paid; and the stub, which is for office record.

On pages that have been clipped indicating that the meters have been out of order during the year, tabs are set on the zinc plates. In printing, these bills are thrown out, as they have to be averaged and so are done on the typewriter. There are six or seven hundred of such bills during the quarter. After the readings have been checked the bills are figured and checked, and when the entire lot has been checked they are sorted according to service stop numbers so as to be easily compared with the ledger cards

before being entered on the bill book. They are then entered on the bill book by typewriter and sorted into lots of four hundred, making five sheets with eighty bills on each sheet.

As fast as each lot is checked and entered the bills comprising it are sent to the City Treasurer's office for collection. It is planned to deliver all bills to the City Treasurer about ten days before the date of collection.

Upon receipt of the water bills from the Department of Public Works a notice is mailed to each consumer. In the case of annual bills, the legal notice is by advertisement in the daily papers, but notice by mail is sent also, as a matter of courtesy.

At the expiration of the ten-day period allowed for payment, a notice is mailed to those whose bills remain unpaid, warning that unless the bill is paid within a definite time, the water may be shut off for non-payment. Usually about a 48-hour notice is given, the notice resulting in the payment of a large percentage of delinquent accounts.

In case of those still remaining unpaid, another notice is sent by registered mail, warning that the water will be shut off.

Upon receipt of the return card from post office the list of unpaid bills is reported to the Commissioner of Public Works. When the stops have been closed for non-payment, the amount of the bill, together with a penalty of two dollars, must be paid before reopening.

The Water Office and Meter Department comprise the following clerks, inspectors, etc.:

Chief clerk,
2 counter clerks,
5 entry clerks,
2 billing machine clerks,
Chief meter inspector,
10 meter inspectors,
Superintendent of meters,
Foreman,
2 machinists,
2 inspectors of service stops,
6 plumbers,
5 express auto trucks.

DISTRIBUTION AND MAINTENANCE — PROVIDENCE, R. I., WATER WORKS.

BY S. FRANK NOLAN.*

[*Read September 14, 1926.*]

The distribution system of Providence has been under construction since 1870. During the first five years 110 miles were laid. Since then construction, although continuous, has been at a much slower rate. At present we have 453 miles of cast-iron pipe ranging from 6 in. to 42 in. in diameter and in addition 12 miles of special fire service mains. These latter pipes of cast iron range from 6 in. to 24 in. in diameter. There are in use about 40 000 services, both general and fire. These range from ½ in. to 16 in. in diameter.

The system covers Providence and parts of Cranston, Johnston, North Providence, and Warwick. From the start care was used in the selection of material. The workmanship was first-class and this, with the benefit of sound engineering, has given Providence a distribution system which functions well. This is reflected in the report of a recent survey made by the Pitometer Company, no leaks being found in our mains and but two in our lead services.

The trunk mains, two 30-in. cast-iron pipe lines from Sockanosset Reservoir to the city, give no trouble after 50 years of use. We recently made a connection in these mains with the new Scituate lines and the old pipe, when cut, proved to be in excellent condition, exterior coating good, interior surface very little pitted, and a remarkably small amount of scale and mud in the pipe. In the case of a 42-in. trunk main from the same reservoir which was also connected, similar conditions were found.

Valves. Various makes of valves are in use in our system. The first used were made by a local firm and all sizes from 8 in. to 30 in. have given good service since installation. The same make of valve, 6 in. in size, however, had a fault in its construction which, after about 50 years' use, compelled its replacement. This was an iron pin through both disks of the valve, which rusted out in time and left a hole through both disks. The valve disks would rise and lower perfectly but, you can readily see, the valve would still leak. Many of these have been replaced and we expect eventually to replace them all.

We have recently systematized the inspection of all of our valves by the following method: A card index is kept showing the size, make, number of turns, and location of every valve in our system. When a foreman

*Superintendent of Distribution, Providence Water Works.

opens or closes a valve in the course of his work, he makes a return to the office, of this fact, with the date and condition of the valve. This is entered on the card, which is then reversed in the file. At the close of the year all cards not reversed are listed and a gang is sent to operate such gates and report their condition. This insures that every gate will be operated at least once a year.

Most valve repairs are for leaks in the stuffing box. In making these repairs we found much trouble with iron glands, followers, and nuts, so in our recent gates we require these parts to be of bronze. By-passes are not used in our system on gates less than 16 in. in diameter.

Maintenance. All new additions to the system are laid by our men. No ditching machine or power hammers are used. Lead and oakum are used in the joints which are hand caulked.

Due to the loyal and experienced men who have been with the department for many years, we get good work at a fair cost. Instead of letting contractors do our pipe-laying, the work is done by our own force. This means that our regular department men are experienced in repairing and replacement. As a result we have an ample trained force for emergency work.

The mains are laid 4 ft. 8 in. from the surface of the ground to the center of the pipe. This has been sufficient to prevent frozen mains except during the winter of 1917–1918. During that season, many 6-in. and 8-in. mains laid in gravel soil were frozen and burst. No mains over 8 in. in diameter were frozen.

Blowoffs are maintained to insure circulation during severely cold weather, through mains exposed on bridges.

Water is supplied to the higher elevations in Providence from a storage reservoir to which water is pumped from our low-service reservoir. Along the contour, which divides the low from the high service area, gates are set and kept closed. This feature causes many "dead ends," and complaints are frequent of ill-smelling and discolored water. A 1-in. valve and pipe is inserted in the ends of all mains. This pipe is brought up to the surface so that a hose can be attached and the dead ends flushed out.

In case of stopped service pipes or impaired supply, a Blake force pump is used to blow a paper wad through the pipes to clear obstruction. Since the installation of the Filtration Plant, complaints of stopped and impaired services have decreased to a marked degree.

Hydrants. The fire hydrants, of which there are about 2 800 in use in Providence, are of the flush type. No part of the hydrant or encasing box projects above the sidewalk. This type gives very little trouble, as its construction is such that it prevents unauthorized use. The valve of this hydrant is as low as our mains, thus giving frost protection. This valve is a cast-iron ball, faced with rubber where it fits against the copper-faced seat. It is opened by lowering the ball against the pressure in main. The first few turns to open, causes a relief valve within the large valve to

operate, thus filling the barrel of the hydrant, and balancing the pressure each side of the main valve, which lessens the force required to open the main valve.

In Providence all of the fire hydrants are tested and examined at regular periods by the Fire Department. Any defects found at these inspections are noted and a report is made to the Water Department. Repairs are made at once and, due to the frequent and thorough inspections of the firemen, the hydrants are kept in an efficient condition.

We have a rule that between November 1 and April 1, anyone, except Water and Fire Department men, who operates a hydrant must report the fact to these departments. This report results in the making of an inspection of the used hydrant, to see if it has been shut tight. Thus danger of a frozen valve or stem is averted.

When contractors on street construction require water from hydrants we insist that one of the Water Department men operate the hydrant. This man is paid by the contractor and, when not tending the hydrant, he is used by the contractor on other tasks.

In the city of Cranston and town of North Providence post hydrants are used. These hydrants are well designed and well built. We seldom have trouble with them except when used by persons who have no right to use them. The fact that they are out in plain sight and that anyone with an ordinary monkey wrench can open and close them, invites their use. In summer, if not properly closed by such persons, they allow the waste to wash out the ground around the hydrants. In winter this imperfect closing allows the barrel and valve to fill with ice.

The use of Stillson wrenches on these hydrants rounds off the corners of the valve stems. This handicaps the firemen when they use their box wrenches at a fire. We have enlisted the aid of the firemen where this type of hydrant is used, in an effort to prevent use other than for fire purposes.

Services. In all services from the Providence mains lead pipe, from $\frac{5}{8}$ in. to $1\frac{1}{4}$ in. in diameter, is used. Where a greater supply than can be furnished by a $1\frac{1}{4}$-in. pipe is desired, cast-iron pipe from 4 in. to 16 in. in diameter is laid.

In laying the ordinary house service a brass tap is inserted in the side of the main, with a tapping machine. Lead pipe attached to the tap by a solder nipple is carried to a point just back of curb line, where a stop with drip is set. Over this stop is set a cast-iron box with lock cover, the top of which is flush with the sidewalk surface. A piece of lead pipe 16 in. in length, is wiped on to the house end of the stop. This is done to give the house plumber an opportunity to connect his pipe without disturbing the position of our stop or box.

Our lead service pipe is heavier than the ordinary stock pipe, weighing as follows: $\frac{5}{8}$-in. — 4 lbs. per foot, $\frac{3}{4}$-in. — $4\frac{3}{4}$ lbs. per foot, 1-in. — 6 lbs. per foot, and $1\frac{1}{4}$-in. — 9 lbs. per foot.

A gooseneck is left at the main in all lead services. Taps and stops are made to our pattern in use since the system was started.

Construction of services calling for cast-iron pipe, is the same as in our mains. A gate is set in all services between our main and the property line. No joint is allowed under or within a foundation wall. To save claims and liability, all openings in foundation walls for water-supply pipe must be made by owner.

All supplies, of whatever size, for general use are set from main to curb line free of charge. Both pipe and labor used in fire supplies are charged to the property owner, together with the cost of street repairs. A plan showing the proposed fire supply is submitted by the property owner before a permit to connect with our mains is granted. This enables us to control the location of the proposed connection and to prevent interference with parts of our system in actual use.

Emergency and Repair Work. An emergency force is maintained at all times. It consists of two gangs, each having a foreman, truck driver, laborer, and telephone-man. A light 1-ton truck is used. These men work 9 hours per day, 6 days in the week, and alternate on the night shift every other week.

The period from 7 A.M. until 1 P.M. on week days, not covered by these gangs, is taken care of by our yard force.

On Saturday afternoons, Sundays, and holidays the emergency force is made up of foremen and skilled men from the regular laying and service gangs. A list is kept posted in the office showing, at least two months in advance, what days they will be employed.

The emergency gang, of four men, is light, yet it enables us to locate the trouble and make temporary repairs, thus taking care of most of our emergency calls.

Should the task be too much for the foreman when he arrives, he at once calls up the telephone-man he left in our office, and additional men are summoned from their homes. A list of such men is kept handy and up to date.

An efficient telephone-man is invaluable to the emergency force. He can often learn from an excited house-owner some precise facts of his complaint, thus helping the foreman get the correct locations or tools before he starts. In reports from the Fire or Police Departments a few questions by the telephone-man help a great deal.

All foremen sent out on emergency work are men of long experience. This saves rash shut-downs by which general supplies and hydrants are put out of service unnecessarily.

A card index giving the locations of all services, hydrants, and main-line gates is kept in the office for the use of the emergency force.

THE METHODS OF TREATMENT OF THE PROVIDENCE WATER SUPPLY.

BY JULIUS W. BUGBEE.*

[*Read September 14, 1926.*]

A paper describing methods of water purification in Providence was prepared by the writer for the convention of the New England Water Works Association at Rochester in 1924, but it was thought that a brief review of the methods employed might be of interest at this time, in connection with the other papers relating to the Providence water supply.

Source of Supply.

The supply is taken from the Pawtuxet River at Pettaconset, about two miles above the point of discharge into Narragansett Bay.

Above this point the watershed has an area of approximately 200 sq. miles, and a population of over 30 000 with numerous manufacturing establishments, including textile mills, dyehouses, and bleacheries.

Pawtuxet water was introduced into Providence on Thanksgiving Day, 1871, and from that date until 1905, the supply was pumped directly from the river into Sockanosset Reservoir, without treatment.

Filtration.

Contracts were let in May, 1902, and completed in November, 1905, for six open filters of one acre each, but after one winter's experience had demonstrated that the open filters could not be operated satisfactorily, covers were constructed on these six filters, and four acres of covered beds were added.

These filters had a rated capacity of 3 million gal. per acre per day. The sand had an effective size of approximately 0.26 mm. with a uniformity coefficient of 2.3.

Beginning in 1917 and extending through the next two seasons, the entire amount of sand in the beds was removed and thoroughly washed, resulting in a loss of five per cent. of fine material, and an increase in the effective size to 0.34 mm.

Other losses of sand during the life of the plant have reduced the volume in the beds to 85 per cent. of the original amount.

The practice has been to scrape each bed when the loss of head reaches 4 to 4½ ft. During the summer it has been customary to rake the beds when the loss of head has reached 3½ ft., and then to continue the run until

*City Chemist, Providence, R. I.

the loss reaches 4½ ft. These scrapings average ½ in. in thickness, and the sand taken off is piled in the bed until removed semiannually by an ejector. All beds have been re-sanded every summer until last year, when only three beds were done, and no re-sanding has been done during the present year, as the new plant at Kent is expected to supersede the slow sand filters within a short time. The omission of seven beds last year was caused by a discharge in August of strong sulphuric acid from a bleachery about two miles above the filters. Upwards of 1 000 gal. of strong acid escaped from a storage tank into the river, and as it occurred at a time of minimum flow, nearly all of the acid was taken onto the filters. The strength of the acid was sufficient to kill several tons of fish in the river, and its effect on the filters was to destroy all bacterial action, and to convert the gelatinous coating on the sand grains into a slimy mass which clogged the filters. Successive cleanings showed that this slime extended far down into the sand, and it was not thought advisable to risk sub-surface clogging by replacing washed sand above this material. The condition of the beds returned to normal after several weeks of short runs and low bacterial removal, but too late to allow re-sanding.

Lime Treatment.

Since July, 1920, the filter effluent has been treated with hydrated lime, to remove free carbonic acid, which at times reaches 20 parts per million, with a yearly average of 15 parts per million. Sufficient lime is added to maintain a carbonic-acid content of two to three parts per million after treatment. It has been found by frequent tests of water from various parts of the city that this treatment is effectual in preventing corrosion of lead service pipes and house plumbing. A Gauntt dry feeder is used in applying the lime.

Chlorination.

Chlorination has been carried on continuously since May, 1917. Excess chlorine, fifteen minutes after treatment, is maintained at 0.2 part per million. The amount required for this treatment is about 125 lbs. per day, or 0.6 part per million. The apparatus in use consists of two Wallace and Tiernan MDA type panels with injectors, each unit having a capacity of 200 lbs. per day.

Microörganisms.

Microscopic examinations are made each week of water from each of the three distributing reservoirs, and whenever the result of these examinations indicates a possibility of complaint regarding taste or odor, the reservoirs are dosed with copper sulphate. Complaints have generally been due to the presence of *uroglena* or *asterionella*, and a dose of two pounds per million gallons has been found sufficient to remove these organisms.

THE PUMPING STATIONS OF THE PROVIDENCE, R. I., WATER WORKS.

BY JAMES A. MCKENNA.*

[*Read September 14, 1926.*]

After thirteen years, beginning in 1853, the citizens of Providence, three times, most emphatically voted down the project of supplying the city with a system of pure water to serve both domestic and manufacturing consumers. In July, 1866, two months after rejecting the proposition, they just as emphatically voted to have designed and installed a system of pure drinking water that would give an abundant supply to the community. A committee of non-salaried citizens was elected and after a prolonged study of available engineers upon the design and construction of the proposed works, the committee, in October, 1866, called Mr. J. Herbert Shedd, an eminent hydraulic engineer of Boston, to make a professional examination of all possible sources of supply, and to act as chief engineer of the project. Five sites were given careful consideration as possible sources, including investigations as to quantity, quality and economy, and the examination of existing artesian wells. After very exhaustive study, the source of supply which best met the requirements was the Pawtuxet River site, at a point about one-quarter of a mile above the entrance of the Pocasset River, in the town of Cranston, R. I., where a drainage area of 195 sq. miles was available.

The next step was to study the topography of the surrounding country in order to find a suitable site for a reservoir of sufficient size and height to supply the city with water by gravity. Such a site was found on Sockanosset Hill, in the town of Cranston, one mile distant from the source of supply, and at an elevation of 180 ft. above mean high water in the Providence River.

The important question then arose as to the best type, style, and design of pumping engine to meet the necessary requirements. After extended research on pumping engines, both in this country and in Europe, it was finally decided to adopt the so-called Cornish, or mine, type of engine as best suited to fill the necessary requirements. Accordingly, designers and draftsmen were put to work to plan, lay out, and design an engine that would be capable of pumping 9 million gal. of water per 24 hours, against a head of 180 ft.

This designing of an engine necessarily took up considerable time, and as the reservoir and gate houses were well under construction, as well as the laying of the force and leading mains, it was deemed advisable to

*Engineer, Providence Water Works.

set up a temporary pump on the river bank that would be capable of pumping 5 million gal. of water per 24 hours against a 180 ft. head. Accordingly, bids were asked for and submitted, and it was decided to have constructed and installed in a house by itself on the river bank, a 5 million gal. Worthington duplex engine, the boilers for which were built by a local concern, the Providence Steam Engine Company. It was understood that this engine was designed for future and permanent use at Hope Pumping Station; but it was never set up there, as the requirements at this station were of such a nature that it was deemed advisable to keep the Worthington duplex engine on the river bank. At this time not much weight was given the question of economy in pumping engines, the great object being to procure an engine that would deliver a given quantity of water under a specified head in a given time, regardless of cost.

Water was first pumped into Sockanosset Reservoir, November 4, 1871, and turned on to the city Thanksgiving day, November 30, 1871. The first service stop was opened December 1, 1871, at the Providence Opera House.

The average daily record of operation of the Worthington duplex engine was as follows:

Cost of coal delivered by team 5¼ miles from the city (pea, Beaver Meadow) $5.35 per ton; wood, $5.00 per cord (in working out the duty of the engine, 3 lbs. of wood was considered equal to 1 lb. of coal); average hours engine ran per day, 20.18; average daily pounds of coal, 8 484.56; average daily pounds of wood, 133.82; per cent. of ashes and clinkers to total fuel, 17; gallons pumped per pound of fuel, 370; duty per 100 pounds of fuel, 51 319 000 foot-pounds; head against which engine pumped, 170.72 ft.; cost to pump 1 million gal., $13.17.

At this time (1872) this record was considered very good.

During this time, 1872, quite a little work had been done on the foundation for the main building for the permanent pumping station, the dimensions of which were: length of engine house, 129 ft. 8 in.; width of wings, 44 ft. 8 in.; length of boiler house, 178 ft. 8 in.; width of boiler house, 54 ft. 8 in. A space ten feet wide was left between the engine house and boiler house, roofed over, and occupied for a machine shop, etc. The structure is built of Westerly granite and Danvers pressed brick and was designed to receive 4 Cornish engines, each capable of pumping 9 million gal. per 24 hours. During the course of excavation for the foundation, and from borings previously made to the depth of 61½ ft., it was discovered that a heavy bed of quicksand underlay the whole area where the engine house was to be erected. Consequently it was decided to build a wooden platform, 4 ft. thick, and made up of 12-in. x 12-in. hard pine timbers, each layer at right angles to the one beneath it, the seams being caulked watertight.

This platform provided a foundation for the beam walls, side walls of the building, pump, and standpipe. The beam walls are 6 ft. thick, of Danvers brick masonry, and are separate and apart from the walls of the

main building. After the Cornish engine had been running a short time, there were indications of a settlement of the timber foundation, which continued to increase as time went on. After duly considering various plans to remedy this condition, it was decided to drive piles.

Among the most important questions that presented themselves in connection with the plan adopted was the best method of getting 10-in. holes through the platform, through which to drive piles; the best way to prevent the water, with which the surrounding sand was filled, from flowing

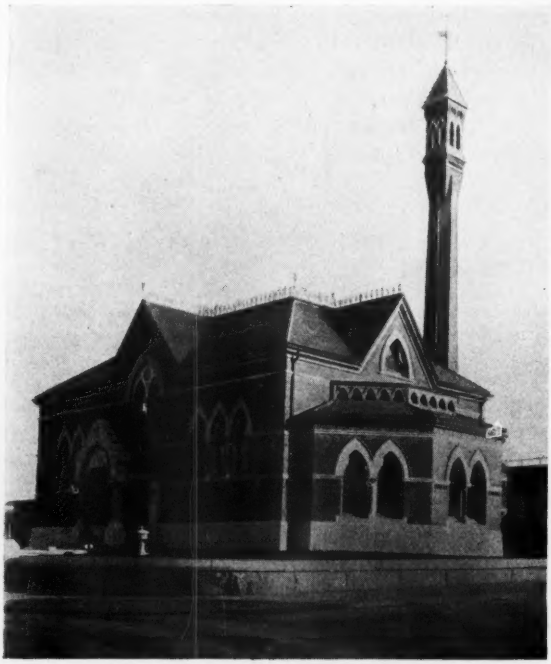

FIG. 1. — THE HOPE PUMPING STATION.

up through the holes when bored and thus bringing up sand; and the most expeditious way of driving the piles to obviate as far as possible disturbance of the interior of the building, since it was necessary to remove the lower floor, which was about 16 ft. from the top of the platform. As the bottom of the filter basin, which lay but a little distance south of the building, was two feet lower than the bottom of the platform, it was thought best to pump out the basin and keep the water level below the platform, thereby draining the sand and preventing water from washing up sand from under the platform. This was accomplished by setting in operation a 15-in. Andrews drainage pump, located on the south side of the basin. In order to drive the piles without entirely removing the floor next above the plat-

form, a driver was made in two sections, of which the lower could be moved about below the floor beams, and the upper moved about above the beams. The piles were then located at those points where the driver could be operated between the iron beams of the floor, the water pipes, etc.

Above the point where the hole was to be bored an iron frame was set up and secured by coach screws. A hole was then bored with a $1\frac{3}{8}$ in. auger. The washer was then taken out, permitting the stem of the 10-in. auger, designed in the Chief Engineer's office, to come up through the iron guide or frame. The auger was then turned by hand by means of a wrench, the thread on the lower end of the stem drawing the auger in as it turned. In places where there was not room to turn the wrench a ratchet was used. The holes were bored to within about half an inch of the bottom of the platform, the remaining portion being left until the pile was driven, to prevent sand from washing in. It was eventually driven out by the pile. Although the water in the basin was kept lower than the bottom of the platform, it found its way, nevertheless, up through any vent, rising over two feet above the top of the platform.

Forty piles were then driven under the pump and about the standpipe. In order to drive those under the pump, the weight box was disconnected at the lower half, the plunger, pump chamber and base of pump, weighing upwards of 100 tons, were loaded on two railroad rails and slid out of place about $13\frac{1}{2}$ ft. and replaced after the piles had been driven.

The piles were 10 in. in diameter, and about 25 ft. long. Those first driven penetrated between six and ten inches, while the last ones would go only about one-half to three-quarters of an inch under the same blow. Each step of the work proved very satisfactory. The sand under the platform was so compacted as to even lift the standpipe somewhat. After the piles had been driven the tops were wedged with oak and with iron wedges. Iron rods $1\frac{1}{2}$ in. in diameter were also driven through the platform and pile, and iron caps were bolted over the top of the pile. The tops of the holes in the platform were beveled, so as to allow for the spread of the top of the pile from the effect of wedging.

This work was commenced September 22 and pushed forward day and night until its completion, November 22, 1879.

To show the magnitude of the Cornish Engine, I will give the finished weights of some of the cast-iron parts:

Beam, cast iron	115 000 lbs.
Cylinder (100 in. diameter)	23 000 lbs.
Cylinder jacket, cast iron	34 500 lbs.
Cylinder head, cast iron	12 500 lbs.
Cylinder bottom, cast iron	15 000 lbs.
Cylinder piston, cast iron	25 000 lbs.
Pillow blocks (2), cast iron	12 000 lbs.
Pillow block bases (2), cast iron	12 000 lbs.
Steam chest and valves, cast iron	9 000 lbs.
Exhaust chest and valves	6 300 lbs.

Equilibrium and side pipes	4 000 lbs.
Exhaust pipes, cast iron	3 000 lbs.
Condenser	9 000 lbs.
Injection pipes, cast iron	2 000 lbs.
Channel plate, cast iron	5 000 lbs.
Air pumps, cast iron	3 400 lbs.
Hot well and delivery pipes, cast iron	6 000 lbs.
Brackets and miscellaneous, cast iron	2 000 lbs.
Base of pump, cast iron	40 000 lbs.
Lower pump chamber, cast iron	40 000 lbs.
Upper pump chamber, cast iron	35 000 lbs.
Stuffing box, stops and barrel, cast iron	13 000 lbs.
Plunger, cast iron	17 500 lbs.
Weight box, cast iron	34 000 lbs.
Weight box cross head, cast iron	10 000 lbs.
Weight box cover, cast iron	2 300 lbs.
Cylinder cover (polished), cast iron	3 000 lbs.
Air pump bracket, cast iron	1 000 lbs.
Cylinder gallery and stairs, cast iron	2 000 lbs.
Weights in piston, cast iron	51 000 lbs.
Weights in plunger, cast iron	45 000 lbs.
Weights in weight box, cast iron	115 000 lbs.
Weights for valve-gear, cast iron	6 000 lbs.
Flooring, cast iron	5 000 lbs.
	718 500 lbs.
Extra Work.	
Three sets of pillow block bases	36 000 lbs.
Base of standpipe	20 000 lbs.
Inlet casting	26 000 lbs.
Outlet casting	26 000 lbs.
Reducer	10 000 lbs.
	118 000 lbs.
Total finished weight of cast iron	836 500 lbs.

Besides this great weight of cast iron there was steel, wrought iron, and brass, to the amount of 85 500 lbs., but after years of daily service with its see-saw movement of about six strokes per minute and an 11-ft. stroke, there has not been any appreciable movement in the wooden foundation since the piles were driven. The average daily operation of the Cornish engine, or "Elephant" as it was called, are herewith presented:

Cost of coal delivered by team 5½ miles from the city (pea, Beaver Meadow, and Cumberland), $5.35 per ton; wood, $5.00 per cord; average hours engine ran per day, 15.09; average daily pounds of coal 10 914; average daily pounds of wood, 642; per cent. of ashes and clinkers to total fuel, 14.6; gallons pumped per pound of fuel, 347; duty per 100 pounds of fuel, 49 372 000 foot-pounds; head against which engine pumped, 170.96 ft.; cost to pump 1 million gal., $14.83.

You will bear in mind that at that time, in the early 70's, skilled labor was receiving $1.50 per day of 10 hours, while ordinary labor was receiving but $1.25 per day of 10 hours. The boilers, a battery of five, were of the

horizontal locomotive type with steam pressure at 45 lbs. The elevation of the ground at the Cornish engine house was 26 ft.; elevation of floor of engine house, 31 ft.; elevation of top of walls, 75 ft.; elevation of ridge, 100.60 ft.; elevation of tower, 112.16 ft.; elevation of the top of chimney of boiler house, 189.26; elevation of bottom of standpipe (before filling), −2 ft.; elevation of top of inside pipe, 181.2 ft.; elevation of top of outside

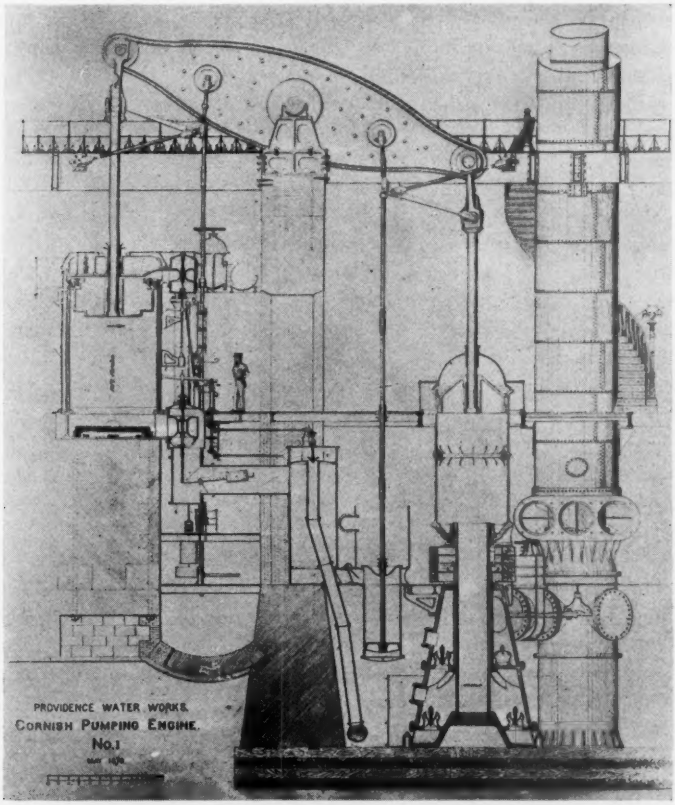

FIG. 2. — SECTION THROUGH CORNISH ENGINE, THE "ELEPHANT," AND WOODEN FOUNDATION, SHOWING STANDPIPE.

pipe, 187.4 ft.; elevation of finial, 211.75 ft. The diameter of the inside pipe was 6½ ft., and the diameter of the outside pipe, 8 ft.

Providence, like Rome, is built on seven hills, the highest being 200 ft. above high water in the Providence River; and to supply that part of the city of too high an altitude to be supplied by gravity from Sockanosset Reservoir, a second reservoir of 76 million gal. capacity was built within the city limits, and a second pumping station built near its northwest corner. The purpose of this station was to house engines that would take

their supply either from the mains in the street or from the reservoir, or both, and supply all that part of the city that has an elevation above 90 ft., a division line being gated off between the high and the low service, at elevation about 90 ft. One of the requirements of the engine builders, who were bidding to furnish and erect a pumping engine, was that it should raise 5 million gal. per 24 hours against a head of 88 ft. As there was no standpipe or reservoir in the high-service district at this time to relieve the pressure, theoretically, in the early morning hours with all faucets closed and no draught on the system, the engine was supposed to stand still.

This performance of a peculiar and special duty consisting in the supplying of an almost constantly varying demand for water, at rates of speed varying from minimum to maximum and with a varying back pressure on the suction side, of 40 ft., was very satisfactorily met by the Corliss engine, the first pumping engine designed by the late George H. Corliss. This engine operated from a vertical shaft on which was placed a cam working horizontally, attached to which were five piston rods working in steam cylinders, and five pump rods attached to plungers in pumps, set alternately,— one steam cylinder and one pump, etc. This peculiar design was dubbed "the spider," but it fulfilled the requirements of the contract and was accepted, irrespective of the cost of operation. The average daily record of the operation of the Corliss engine at Hope Pumping Station follows:

Cost of coal (anthracite), $5.40; wood, $5.00 per cord; average hours engine ran per day, 23.23; average daily pounds of coal, 2 372.34; average daily pounds of wood, 12.76; per cent. of ashes and clinkers to total fuel, 15.8; gallons pumped per pound of fuel, 127; duty per 100 pounds of fuel, 13 041 000 foot-pounds; head against which engine pumped, 88 ft.; cost to pump 1 million gal., $62.29.

This engine was put into commission during the fall of 1872. As the high-service district required constant pumping, a second engine was absolutely necessary; consequently, in 1874, a contract for furnishing and erecting another unit at Hope Station, of 5 million gal. capacity, was executed with the Providence Steam Engine Company. The price paid for the engine was $55 000; this was of the Nagle High Duty type. The average daily record of the operation of this unit follows:

Cost of coal (anthracite), $5.40 per ton; wood, $5.00 per cord; average hours engine ran per day, 23.25; average daily pounds of coal, 1 285.99; average daily pounds of wood, 11.18; per cent. of ashes and clinkers to total fuel, 21; gallons pumped per pound of fuel, 453; duty per 100 pounds of fuel, 46 439 000 foot-pounds; head against which engine pumped, 88 ft.; cost to pump 1 million gal., $30.09.

This engine was put into commission in July, 1875. When the water works was first started, the population of the city of Providence was 57 000, but by 1881 the population had increased to 109 000. As the water-pipe system at this time had spread out into the surburban towns, it became necessary to install new pumping machinery at the main, or Pettaconset pumping station.

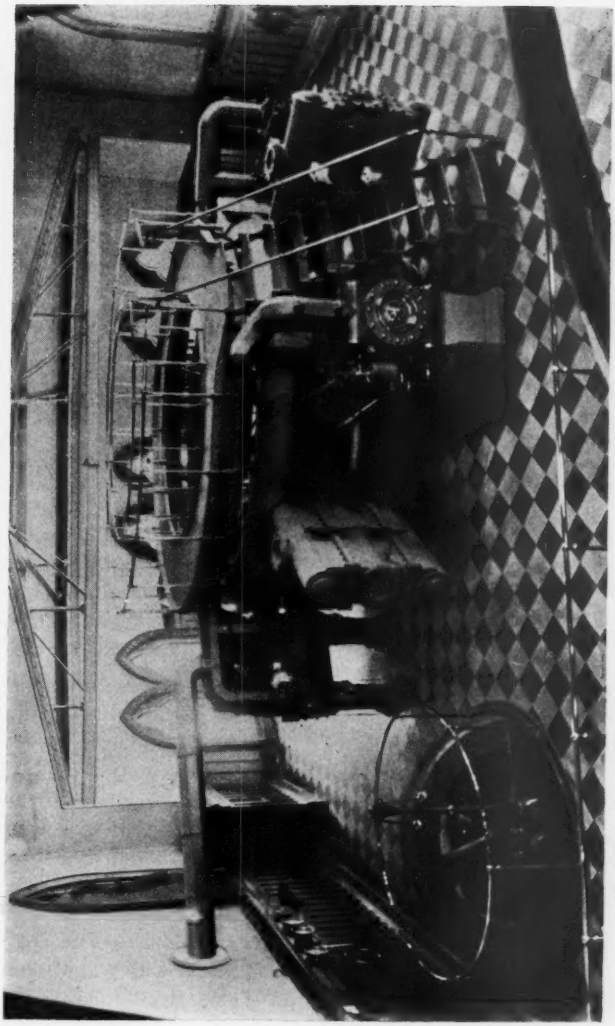

FIG 3. — THE "SPIDER," THE FIRST PUMPING ENGINE BUILT BY GEORGE H. CORLISS.

At this particular time Mr. George H. Corliss had on his hands a pumping engine designed for the sewer system of the city of Boston, and he made the very favorable offer to the city of Providence, to furnish and house his engine and boilers in a suitable brick building on the river bank and connect his pump well direct with the river with the necessary screens, etc., for $100 000. He guaranteed to pump 9 million gal. to Sockanosset Reservoir per 24 hours, with a duty of 100 million foot-pounds per 100 pounds of coal consumed. In case Mr. Corliss failed to fulfill his promises, he was to remove the engine, boilers, house, etc., at his own expense, and to leave the ground in the same condition as when he first broke soil. Three days previous to the trial, a test was made to ascertain the actual quantity of water delivered into Sockanosset Reservoir, as compared with the theoretical displacement of the plungers of the pumps. This was determined by means of a weir located at the gate chamber of the reservoir. Observations were taken at this weir in a thorough and careful manner while the engine was pumping at the rate of 9 065 000 gal. per 24 hours, and it was found that for every 100 gal. displaced by the plungers of the pumps, 99.5 gal. were delivered into the reservoir. This is the most favorable result that has been brought to my knowledge. At different times, May 19 and 20, the engine pumped at the rate of 12 million gal. per 24 hours. The trial was commenced Monday morning, May 22, and ceased Saturday evening, May 27. The average daily operations of this engine follow:

Cost of coal delivered by team, 5½ miles from the city (Cumberland), $4.95 per ton; wood, $5.00 per cord; average hours engine ran per day, 12.5; average daily pounds of coal, 6 056; average daily pounds of wood, 75; per cent. of ashes and clinkers to total fuel, 9.1; gallons pumped per pound of fuel, 777; duty per 100 pounds of fuel, based on the total coal fed into the furnaces, 113 271 000 foot-pounds.

If based on the fuel used only while the engine was running, the duty would be 138 035 000 foot-pounds. Based on the total fuel fed into the furnaces the engine developed a duty 13.8 per cent. more than was guaranteed, and accordingly in June, 1882, the engine and house were transferred to the city. This engine is an A frame, vertical, compound, fly-wheel type, and has four pumps that work like a horse trotting. The cost to pump 1 million gal. was $8.24. The next engine purchased by the city and located at the main, or Pettaconset pumping station was a Worthington vertical triple-expansion high-duty pumping engine with oscillating cylinders and a capacity of 15 million gal. per 24 hours. This engine gave a very good account of itself and supplied the city with water for 10 years. An average daily record of the operation of this engine follows:

Cost of coal delivered by team 5¼ miles from the city (Beaver Meadow and George's Creek, Cumberland), $4.50 per ton; wood, $5.00 per cord; average daily pounds of coal, 1 606; average daily pounds of wood, 3; gallons pumped per pound of fuel, 694; head against which engine pumped, 175.88; duty per 100 pounds of fuel, 101 828 300 foot-pounds; cost to pump 1 million gal., $5.26.

In 1896 the old low-duty Corliss engine at Hope Pumping Station (the "Spider") was replaced by a Holly horizontal compound fly-wheel engine, built by Holly Manufacturing Company. This had a capacity of 5 million gal. per 24 hours. An average daily record of the operation of this engine follows:

Cost of coal (anthracite, egg, Wilkesbarre), $5.31; cost of wood, $5.00 per cord; average daily pounds of coal, 3 161; gallons pumped per pound of fuel, 555; head against which engine pumped, 139 ft.; duty per 100 pounds of fuel, 64 141 800 foot-pounds; cost to pump 1 million gal., $11.63.

Providence by this time (1905) had increased so that the population was about 200 000, and the people supplied with water in the suburbs about 15 000, making a total of 215 000 persons served, with an average daily consumption of about 15 million gal. As this was the capacity of our largest pumping engine, it was deemed expedient to contract for a new engine that would be capable of supplying the city with water for some time to come. Consequently, in 1905, a contract was made for an Allis-Chalmers vertical triple-expansion engine, with a daily capacity of 25 million gal. This engine was started in August, 1905, and ran continuously until March 1, 1906, when an official test was made. During the 12 hours of the test the engine pumped 12 730 000 gal. It ran continuously for over 24 hours, pumping more than the 25 million gal. The engine exceeded the contract requirements of 175 million foot-pounds per 1 000 pounds of dry steam, giving a duty of 179 476 000 foot-pounds.

This has been a most remarkable engine. The repairs have been very small and the unit has run, practically speaking, night and day ever since its installation, and is still in service. After 20 years the record of operation of this very economical engine last year was as follows:

Cost of coal delivered by truck 5¼ miles from the city (bituminous, New River), $6.27 per gross ton; number of days on which engine ran, 349; average daily pounds of coal, 26 408; per cent. of ashes and clinkers to total fuel, 7.9; gallons pumped per pound of fuel, 859; duty per 100 pounds of fuel, 129 027 662 foot-pounds; head against which engine pumped, 180.09 ft.; cost to pump 1 million gal., $7.72.

In case this engine should be out of service, or the daily consumption should exceed the capacity of the engine, a 30 million gal. centrifugal pump was installed in 1914. This pump was a De Laval horizontal centrifugal, direct — connected to a General Electric 2 200 volt A.C. 1 300 h.p. motor. Current was purchased from the Narragansett Electric Lighting Company. This pump, in connection with the Allis-Chalmers, is expected to furnish the city with water while the new extension to the water supply is being built.

In 1910, at Hope Pumping Station, a Worthington high-duty horizontal triple-expansion engine of 10 million gal. capacity was installed. The duty guaranteed was 135 million foot-pounds for 1 000 lbs. of dry steam, while pumping at the rate of 10 million gal. per 24 hours. A test made on September 1 showed that the engine pumped at the rate of 10 085 000

gal. per 24 hours, and developed a duty of 141 million foot-pounds per 1 000 lbs. of dry steam. The engine was tested under all the various conditions met with in actual service at this station, and proved equal to them all. After 16 years of faithful service this engine, which is in operation today, gave an operating record for 1925 as follows:

Cost of coal, $6.58 per gross ton; cost of wood, $7.50 per cord; number of days on which engine ran, 315; average daily pounds of fuel, 9 312; average daily pounds of wood, 3; per cent. of ashes and clinkers to total fuel, 18.7; gallons pumped per pound of fuel, 408; duty per 100 pounds of fuel, 55 195 479 foot-pounds; head against which engine pumped, 162.12 ft.; cost to pump 1 million gal., $22.21.

This record of 10 pumping engines, covering a period of 55 years, gives a good idea of the rapid strides made by designing engineers, in the economy of such units. For instance, take the "Spider," Corliss's first pumping engine, when labor and fuel were cheap, cost $62.29 to pump 1 million gal. Today, with labor and fuel high, it would cost about $200.00 to pump 1 million gal., and with a daily consumption of about 25 million gal., as we have at the present time, it would cost about $5 000 per day — a prohibitive sum. The question now to be considered is, "Will the next 55 years be able to produce engineers who will be able to reduce the cost of pumping in the same ratio?" Who of us will live to see?

PROVIDENCE, R. I., WATER SUPPLY — THE SCITUATE DAM.

BY FRANCIS B. MARSH.*

[*Read September 16, 1926.*]

The new water supply of Providence was described in a paper by Frank E. Winsor, chief engineer of the Providence Water Supply Board, published in the JOURNAL of this Association for September, 1922. That paper described the foundation work for the Scituate Dam and quoted extracts from the specifications. It also presented the results of experiments that were made on the rate of percolation of water through soils and fine sands. The present paper is mainly concerned with the operations of placing the embankment and the record of data that may prove useful in the design of similar earth structures.

Those of us who have been associated with the construction of the Scituate Dam are quite proud of the structure. It is therefore fitting for the author to acknowledge here that it was largely designed before February, 1919, when he became connected with the work. At that time the cross-section had been determined, the gate house and control works designed, and even some preliminary construction completed. The force organized by Mr. Winsor in 1916, but broken up by the war, had included William C. Pickersgill as designing engineer, Karl R. Kennison, and several other members of this Association. The late Frederic P. Stearns as consulting engineer had given a great deal of personal attention to the layout and design. The construction operations have been carried out under the able direction of William W. Peabody, deputy chief engineer, with James V. Turner, resident engineer, at the dam and dike.

The main dam of the Scituate Reservoir is an earth structure about 3 200 ft. long on top, with a maximum height of about 180 ft. above the lowest point of the rock foundation or 100 ft. above the former river bed. Adjacent to the east end is the dike, about 4 000 ft. long, with a maximum height of about 33 ft. above the original surface. The essential parts of the dam and dike were completed and storage of water was begun November 10, 1925, although some of the finishing touches, such as grassing the downstream slopes, road construction on top, gate-house superstructure, etc., were left until 1926.

The upstream and downstream portions of the dam are composed of sand, gravel, and small boulders, obtained as the run of excavation, mainly from a borrow pit in the reservoir basin about half a mile upstream. Nearly all of this porous material was placed by dumping from tracks and washing into position with hose streams, or by dumping into pools of water. The impervious central portion or core has a maximum thickness of 77 ft. and is

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built of soil stripped from the reservoir basin, spread and rolled in 6-in. layers in accordance with the specifications quoted in the paper already referred to. The soil core and the use of water instead of rolling for consolidating the porous backing, are the points of particular interest in this structure. The disposition of the riprap on the upstream face is also worthy of attention. This was largely based on the experience gained at the dikes of Wachusett Reservoir and it is believed will give a maximum of slope protection at a reasonable cost.

The excavation of the dam foundation, and the grouting and placing of concrete blanket and low cut-off walls on the rock, were described by Mr. Winsor in the earlier paper. Barring and wedging and cleaning up of the rock foundation without the use of explosives involved a payment for 8 221 cubic yards of rock excavation, including an arbitrary minimum thickness of 6 in., fixed in advance by the specifications where the bottom was satisfactorily prepared, even though no appreciable quantity of rock was removed. The depth of this rock excavation varied from nothing to about 14 ft. About 3 000 cubic yards were taken out between Stations 12 and 15. A total of something over 300 holes was drilled for grouting the foundation, with a total length of 6 093 linear ft. of hole, 30 ft. being the maximum depth. A total of 3 160 cubic yards of grout was forced into these holes under a pressure generally of about 10 lbs. per sq. in. The grout was usually mixed one part of Portland cement to 8 or 10 parts water, but was thickened to about 1 to 5 occasionally. No sand was used in the grout. Concrete for the blanket and the low cut-off walls on the rock foundation amounted to 5 708 cubic yards. All the above quantities are for the dam only, including Contracts 3, 8, and 11, but do not include the quantities for the dike. The bulk of the work was done under Contract 8, but some preparatory work was done under Contract 11 and the stream-control conduit was built and its foundation grouted under Contract 3.

The concrete blanket was omitted from the dike foundation, but otherwise it was treated the same as that for the dam, except at the east end where the dike is very low and the slopes were flattened without carrying the foundation to rock, which was quite deep. Grout used for the dike foundation averaged 0.38 cubic yard per linear foot of dike grouted, as compared with 1.06 cubic yards per linear foot for the portion of the dam east of the stream-control conduit. Rock excavation for the dike amounted to 2.31 cubic yards per linear foot, and the grout holes drilled amounted to 1.57 linear ft. of hole per linear foot of dike so treated, these figures comparing with 1.85 cubic yards and 1.65 linear ft., respectively, for the portion of the dam east of the stream-control conduit. A plan and profile of the dam and dike and sections of both structures are shown on the accompanying drawings. (Figs. 1–4.)

The placing of the soil core became more or less of a routine affair of dumping, spreading in 6-in. layers, and rolling, after the low portion in the bottom of the trench was filled up enough to give adequate working

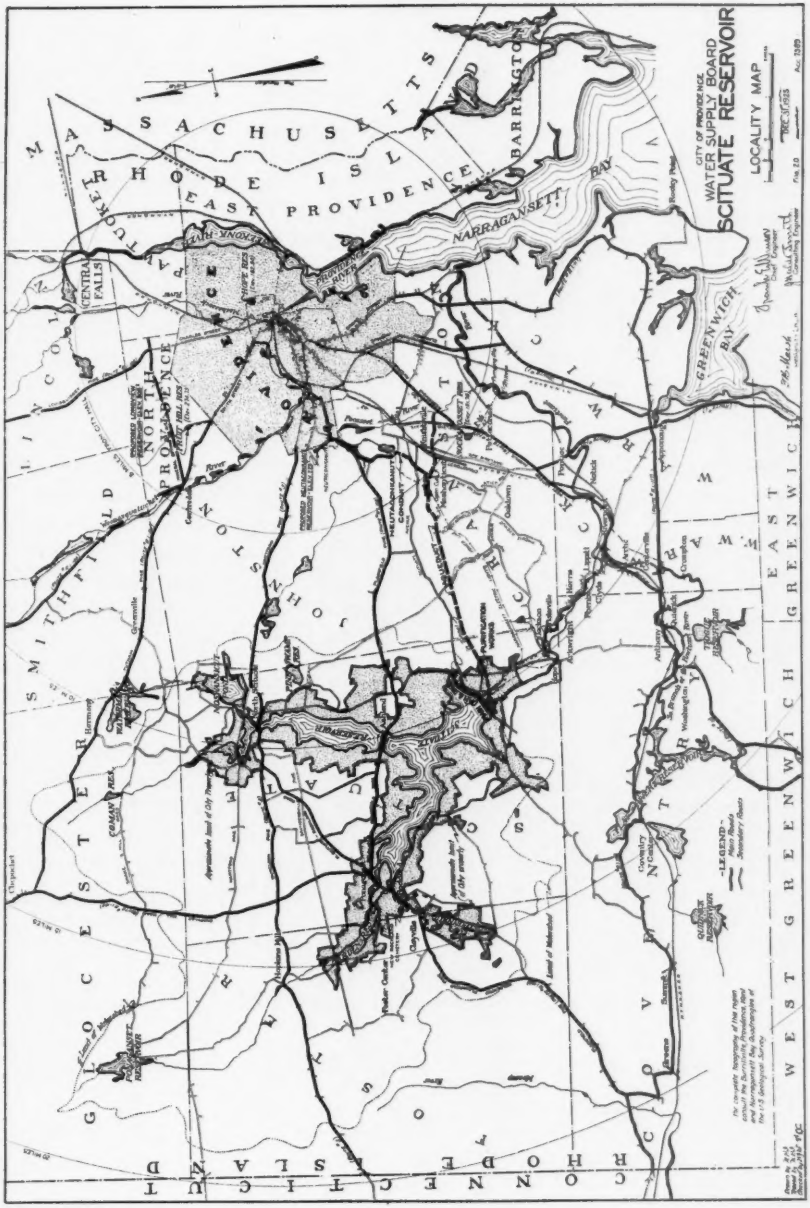


FIG. 1. — LOCALITY MAP.

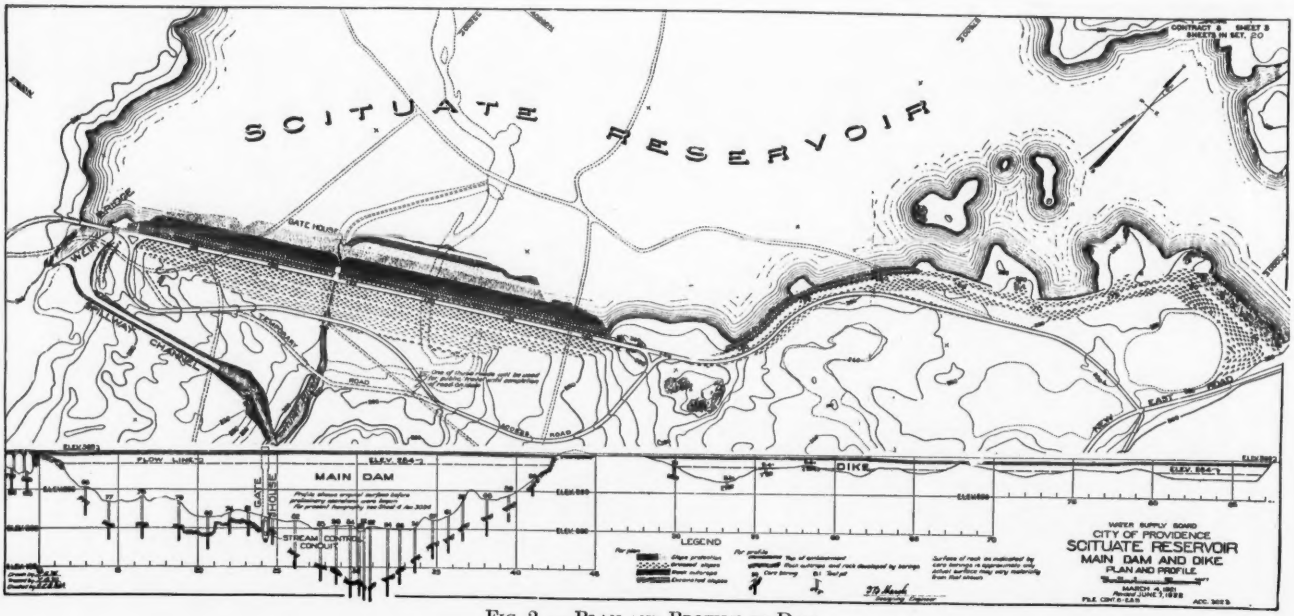


FIG. 2. — PLAN AND PROFILE OF DAM.

area. The methods employed did not differ materially from those used on similar work elsewhere. Stones as large as 6 or 8 in. in maximum size were permitted in the soil core so long as they did not occur in nests and did not interfere with satisfactory rolling. The punching down of such stones into the already compacted material, as the roller went over them, was felt to be an advantage if anything. Roots were removed from the soil during spreading. Three tracks were found most convenient to dump the soil from when the core was 77 ft. wide; only two could be used to advantage when it narrowed to 60 ft., and only a single track at 30 ft., while it made a very cramped area for spreading and rolling at the top where the core is only 15 ft. wide.

The operation of placing the soil core constituted a distinct separation between the two porous parts of the dam, the upstream and the downstream backing. The backing could be placed at times when it was impossible to work on the core, and the good generalship of M. J. Look, Vice-President and Manager for Winston & Company, Inc., contractors for the dam, was nowhere better illustrated than in his planning operations with a view to keeping the core materially higher than the backing as fall approached, with its short, damp days and its freezing and thawing, which made the top of the soil core a sticky mess that could not be worked on. At those times the available force could be concentrated on placing the porous backing. This work was continued well into the winter, utilizing the resource of maintaining a pool of water several feet deep on top of the porous material already placed, and dumping into the edge of the pool even when the ice had to be broken in the morning. By this means assurance was given that chunks of frozen material would be thawed out under water as the fill progressed. The bulk of the porous material was placed by the other method, of dumping from the track and washing down a slope by heavy hose streams, and the hard beach effect produced in this way demonstrated conclusively the compactness of the fill. There was some tendency for the coarser particles to settle out first, carrying the finer sand down the slope to the pool at the low point. With no clay in the material there was no particular harm in this. The amount of water used in compacting was, roughly, about equal to the volume of the embankment compacted by it.

The following table shows the dates on which the placing of both soil core and porous backing were stopped because of weather conditions, and when they were resumed. In the winter of 1922–23 the refilling in the deep

	Stopped placing.		Resumed placing.	
	Soil core.	Porous material.	Porous material.	Soil core.
Winter of 1922–3...	December 7	January 3	January 27	April 12
Winter of 1923–4...	November 30	February 9	March 8	April 15
Winter of 1924–5...	December 13	January 3	March 9	April 1

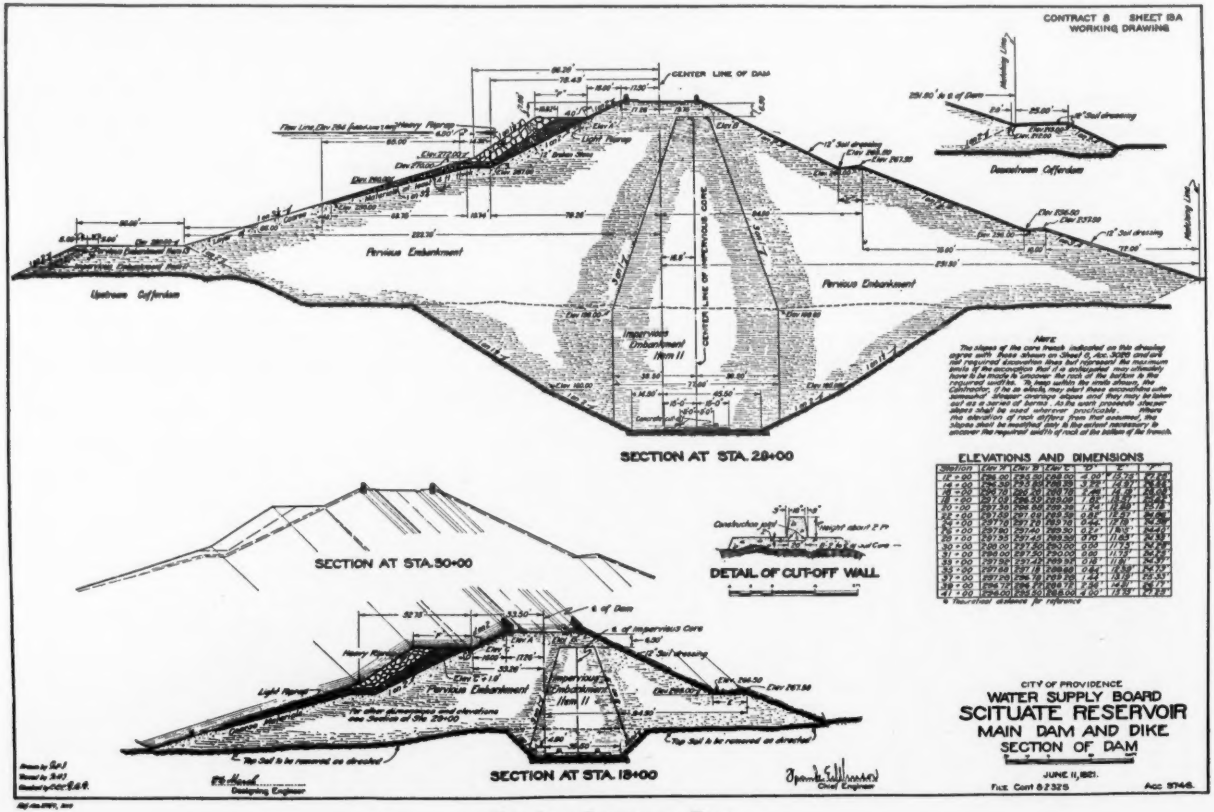


FIG. 3. — SECTION OF DAM.

portion of the core trench was still 20 ft. below normal ground water level and the porous material was placed by dumping into the ponds of rising ground water maintained as pump sumps either side of the soil core. The soil core of the dam was completed November 26, 1924, although the similar work on the dike was not completed till the following season.

A well-studied plan for doing the work with a series of narrow-gage tracks for handling both excavation from the core trench and refilling and embanking, had been prepared and was available to the bidders in advance of letting the contract. This plan of operations was generally adhered to by the contractor, who used 21-ton dinkies and 4-yard dump cars. During the excavation the maximum grade on main-line track was about 5 per cent., but occasional grades as high as 8 per cent. were used on short loading tracks, where five 4-yard cars required two 21-ton engines. With grades up to 5 per cent. a single locomotive was generally sufficient. A transverse cableway on movable towers, with an 805-ft. span, was particularly useful in handling materials and plant in the deepest part of the core trench excavation and refilling.

It is quite easy to underestimate the time required for the excavation and refilling of a deep dam foundation, even where, like this one, there are no special foundation difficulties and the work is pushed energetically. The deepest part of the Scituate Dam foundation was about 80 ft. below the old stream bed and there were about 300 000 cubic yards of material to be excavated and refilled below a horizontal plane at that level. The contract was awarded in May, 1921. Excavation was carried on continuously throughout the winter of 1921–22, and the refilling of the deep portion of the core trench was begun in August, 1922. Two years after the award of the contract the deep portion of the core trench still lacked 15 ft. of being up to the level of the original surface. Two years thereafter were necessary to complete the soil core, and still another year to complete the porous backing and place riprap, top soil, etc. In other words, the portion of the dam below ground took nearly as long to build and, incidentally, cost nearly as much as the portion above ground.

The accompanying tabulation records the progress on refill and embankment for the dam and dike, the figures being for the estimate month, ending on the 10th of the month stated. Refilling the deep portion of core trench began in August, 1922. Quantities of pervious material placed previously were mainly from the core trench excavation, put directly into the portion of dam embankment immediately west of the stream-control conduit, the foundation of which had been prepared for such purpose under a small preliminary contract.

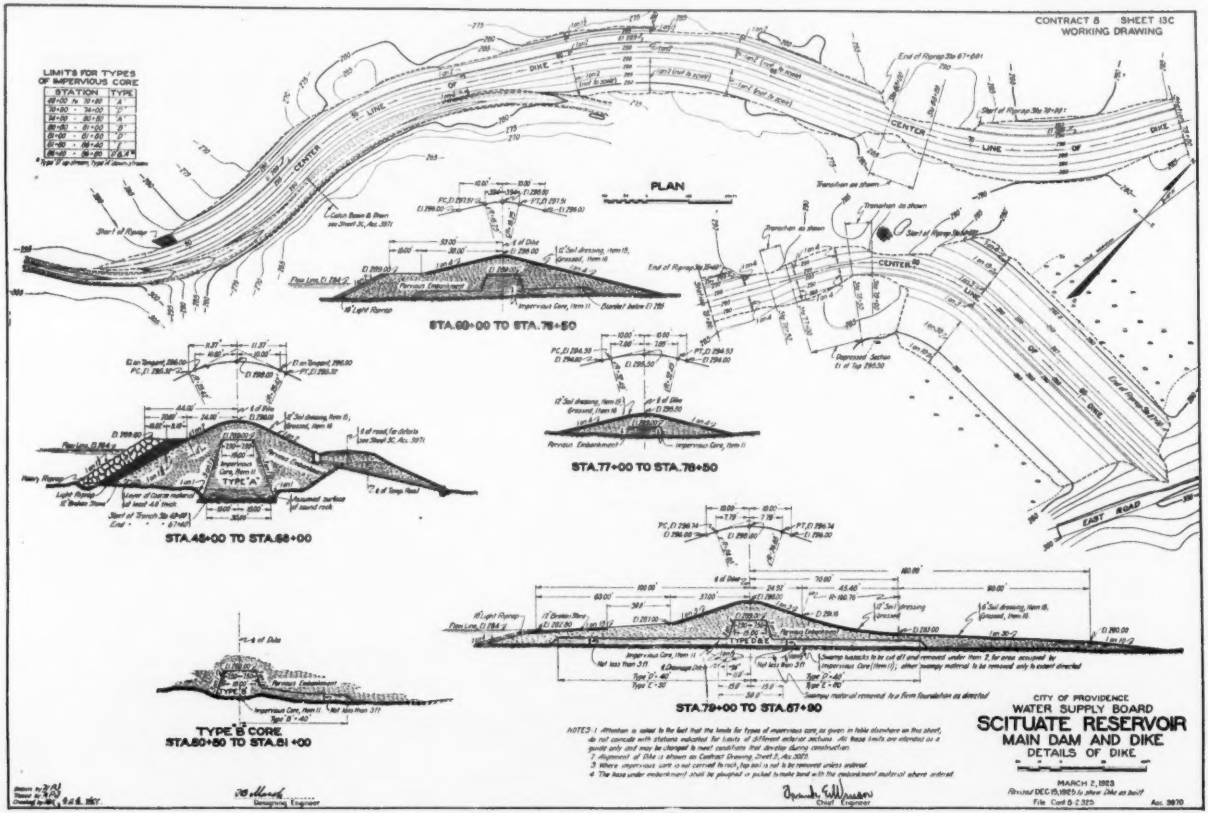


FIG. 4. — DETAILS OF DIKE.

PROGRESS ON EMBANKMENT.

(From approximate monthly estimates.)

		Soil Core cu. yd.	Pervious Embankment cu. yd.
Contract 11, 1919 and 1920		16 000	55 926
Contract 8, previous to August 10, 1922		35 300	257 700
1922.	September	16 200	3 200
	October	23 200	20 150
	November	28 040	33 100
	December	22 990	18 950
1923.	January	0	10 000
	February	0	8 000
	March	0	6 800
	April	200	23 500
	May	7 878	41 300
	June	24 652	23 400
	July	28 940	31 000
	August	35 720	80 400
	September	32 480	110 100
	October	32 640	79 400
	November	24 460	76 000
	December	16 800	82 000
1924.	January	1 880	71 000
	February	0	69 000
	March and April	120	85 500
	May	14 600	89 000
	June	33 460	88 200
	July	32 440	116 660
	August	31 280	80 200
	September	21 660	71 000
	October	30 680	81 000
	November	22 600	89 900
	December	4 380	63 600
1925.	January	0	18 970
	March	0	1 600
	April	1 400	59 000
	May	8 400	49 000
	June	15 200	52 000
	July	2 700	55 000
	August	0	12 000
	September	0	4 800
	October	0	1 000
	November	0	1 000
Total to November 10, 1925, for dam and dike		566 300	2 120 356
For dam only		518 400	2 019 926

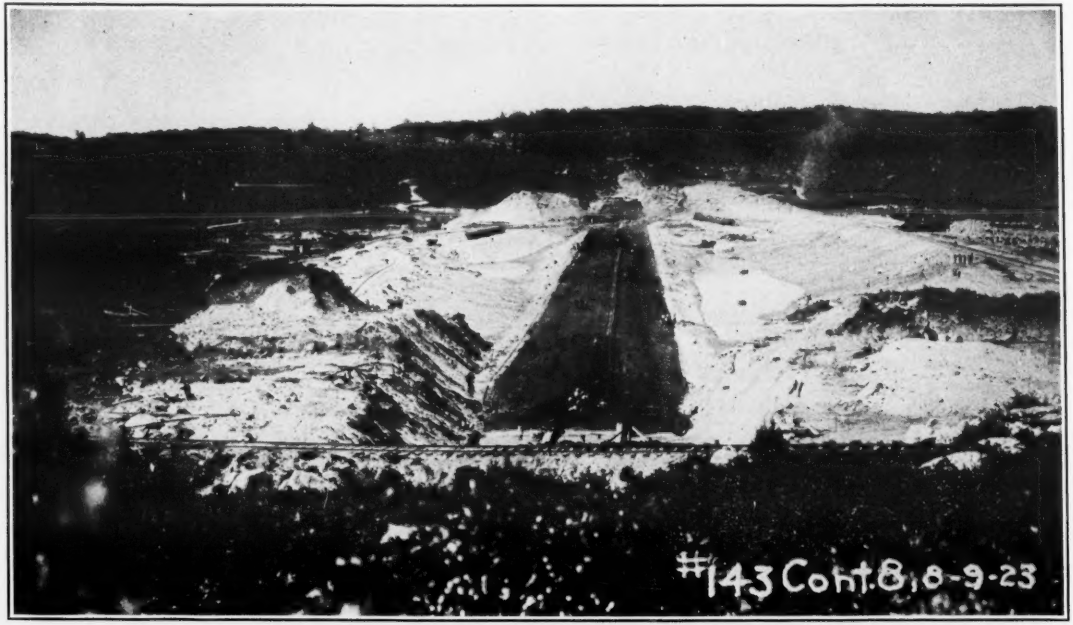


FIG. 5. — SCITUATE DAM, LOOKING WEST FROM EAST END.

Showing conditions August 9, 1923, porous material being washed from tracks at either side of core and upstream and downstream edges. Cable tower at right stands on upstream cofferdam, Elev. 230. Core opposite pools is about Elev. 210.

Possible settlement of the Scituate Dam after completion was allowed for by building the top to 15 ft. above the flow line at the point of maximum height, whereas at the ends it is only 13 ft. above the flow line. Records are being kept of this settlement, bench marks having been placed in the top of the dam for this purpose last December. On August 17, 1926, the elevations of these bench marks were taken. A point 10 ft. upstream from the center line of the dam at Station 28 was found to have settled 0.34 ft., while a point 14 ft. downstream at the same station had settled only 0.16 ft., the fill under the latter consisting of 5 ft. of pervious material and 134 ft. of rolled soil, and under the former 58 ft. of pervious material and 81 ft. of rolled soil.

Another matter of interest to designers, about which it was hoped to get some data, is the ground-water level in the portion of the dam downstream from the core. With this in mind, wash borings were sunk last winter at Stations 20, 27, and 33 along the 266. berm on the downstream face of the dam and opposite them at the downstream toe of the dam. Since March 3, 1926, records have been kept of the ground-water levels in these six borings and in a vent pipe at the downstream toe of the dam at Station 24+25. At Station 20 the readings in these pipes indicated a water level last March about 3 in. higher under the berm than at the toe of the dam, and this difference gradually increased to about 6 in. in June, since which time it has remained fairly constant. At Stations 27 and 33 the differences are the other way, the level being 6 to 9 in. higher at the downstream toe than under the berm. The probable explanation of this is that the ground water at the toe of the dam flows toward the core near the surface and escapes downstream again to the river through a more porous layer of gravel at a lower elevation that was intercepted by the excavation for the dam foundation. In any case, these water levels show clearly that there is no material seepage of water from the reservoir through the core.

The water level in the Scituate Reservoir gradually rose after storage began, on November 10, 1925. It was at Elev. 240 early in January and reached a maximum of 23 billion gal. at Elev. 269.76 the last of May, there being a recession of nearly 3 ft. from that time to the end of August. The former stream bed at the site of the dam was about Elev. 198. The rate of filling of the reservoir was limited by the terms of the legislative act under which the work was done, which provided that from the time when the city began to store water to the time when for the first time, 20 billion gal. should have been stored "said City shall not during any week day diminish the flow of such branch immediately below the dam . . . below the amount which would run in such branch if the reservoir or reservoirs built by said city did not exist, except that when such flow of said branch would exceed 20 million gal. per day said city may hold and store all the water in excess of said 20 million gal." The total capacity of the reservoir is about 37 000 million gal., and the drainage area 92.8 sq. miles. It is expected that the new supply will be put into service during the early fall of 1926. Photographs taken during construction are shown in Figs. 5–11.

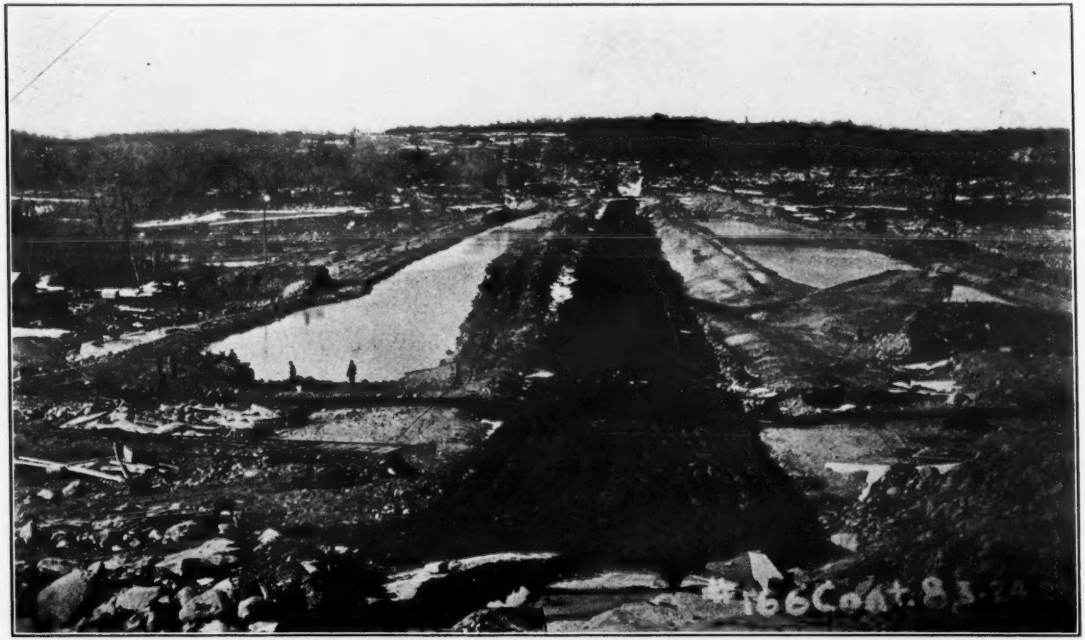


FIG. 6. — SCITUATE DAM, LOOKING WEST FROM EAST END.

Showing condition after winter work, porous material being dumped into pools; upstream pool at right about Elev. 232, downstream about Elev. 240. March 24, 1924.

One question that designers would like to have answered is how thin it would be possible to build such a soil core as that of the Scituate Dam and still have it impervious. It may be that a materially thinner core would have been sufficiently effective. Experience with other similar structures will be useful for comparison. In any case, it is quite clear that a core of soil must be built in the dry in thin layers thoroughly consolidated by rolling.

In the hope of stimulating discussion there are presented herewith some sketches of suggested types of earth dam. (Fig. 12.) These are intended not as alternatives to the Scituate design but rather as suggestive of some possibilities in the design of such structures. Instead of being near the center of the structure, as is the case with the Scituate Dam, the soil core might be placed near the upstream face, as shown in Type No. 1. This avoids the separation of the porous part of the dam into two parts, provides a large area where the excavation from the core trench can be disposed of directly in embankment, and permits the porous portion of the dam to be worked on advantageously before the core trench is completed. In such a design as this the porous material might be placed by means of one or more light steel trestles left embedded in the fill and raised by additional lifts as the work progressed, material being dumped from these trestles and washed transversely by hose streams in such a manner as was done by the New England Power Company at their recently completed Whitingham Dam in Vermont.

The use of trestles involves a consideration of their effect on the subsequent settlement of the embankment. It is not believed that the rusting and possible ultimate disintegration of the steel would affect this appreciably, since the rust would occupy a greater space than the original steel, but unless the greatest care is taken the presence of the trestle would probably affect the compactness of the fill in its immediate vicinity, resulting in a greater subsequent settlement near the trestle than elsewhere. This condition is likely to be aggravated by the fact that the compacting of a porous fill by hose streams is less effective directly at the point of deposition of the materials than it is at either side, where the water actually transports the particles and permits their readjustment one to another.

The author therefore believes that trestles should be permitted in an earth dam only when precautions are taken to secure a compact fill at the trestle. Something along this line might be accomplished perhaps by an apron at the track level on the trestle, causing the material to be dumped an appreciable distance either side of the trestle, from which point it could then be washed toward the trestle.

The porous backing of such a dam as Type No. 1 can probably be placed to best advantage by dumping at the upstream and downstream edges and washing toward the center. With material containing clay or even a large proportion of very fine sand there might develop difficulties due to lack of drainage, but for materials such as those used at the Scituate Dam such a method should be eminently satisfactory from both the engineer's standpoint and that of the contractor.

FIG. 7. — SCITUATE DAM, JULY 15, 1924; LOOKING WEST FROM EAST END; SOIL CORE IN FOREGROUND ABOUT ELEV. 270.

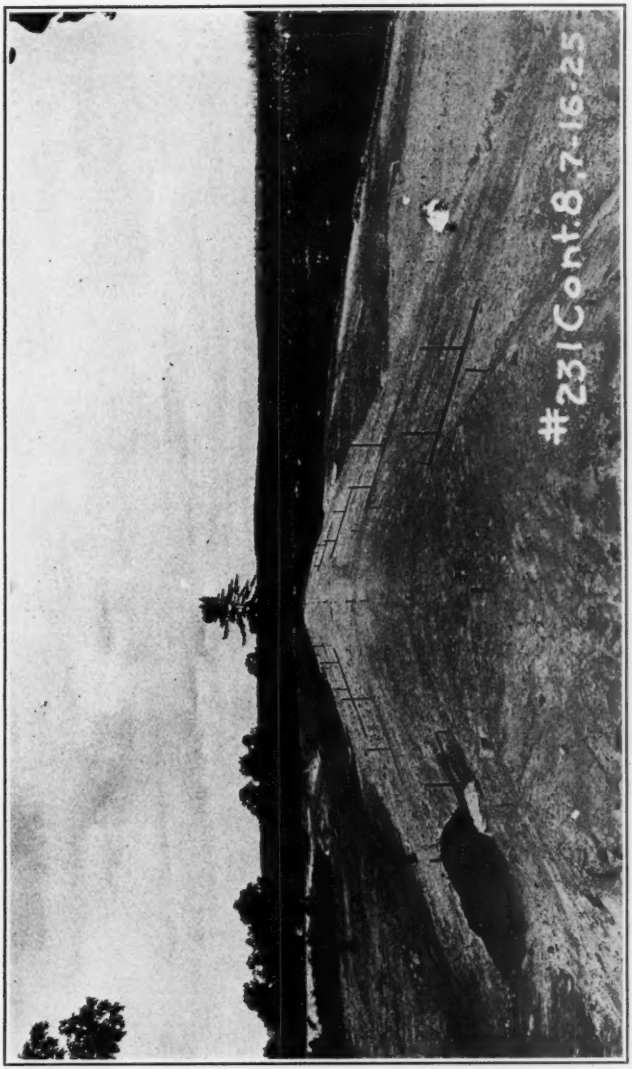


FIG. 8. — EAST END OF DIKE, LOOKING WEST, ALL READY FOR SOIL DRESSING; JULY 16, 1925.

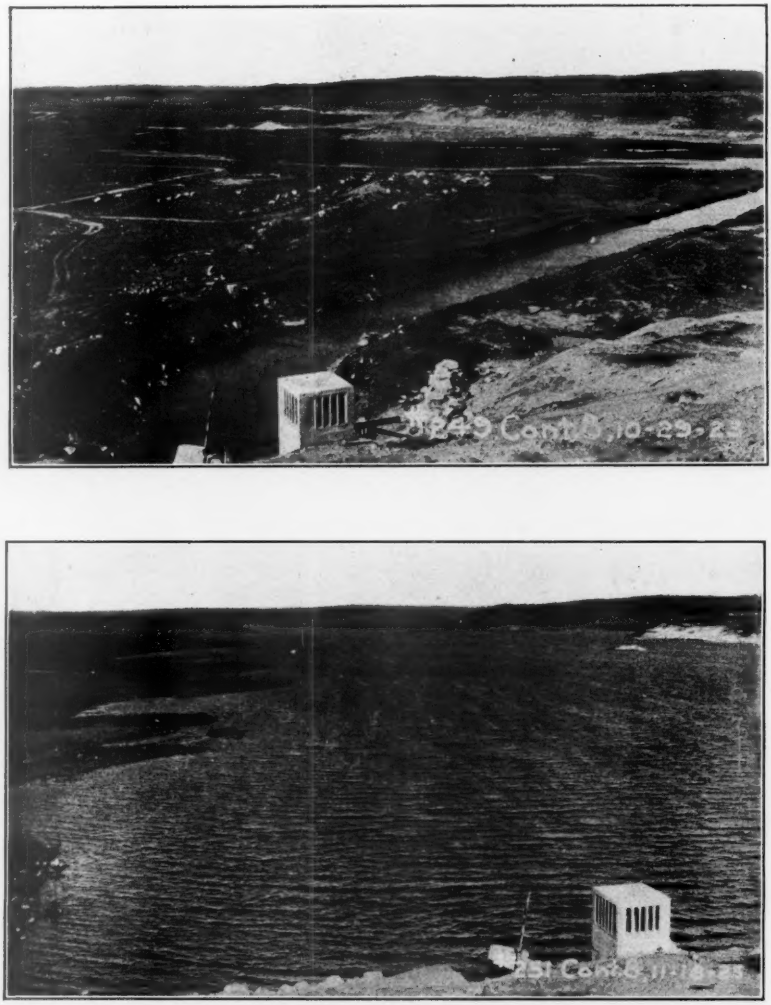


FIG. 9. — BEFORE AND AFTER.

Upper view shows reservoir as it appeared October 29, 1925, from top of dam; lower view on November 18, 1925, eight days after storage began; water at Elev. 222. Intermediate intake in foreground, nicknamed the "mausoleum."

FIG. 10. — WASTE WEIR.

Bridge and west end of dam, water stored in reservoir showing in background; grooves in top of weir are for flashboard standards; December 16, 1925.

The building up of the outer edges of this porous fill would be the most troublesome part of the process, and these would be the places where compacting would be least thorough. However, a slight settlement here need not be of much consequence so long as the interior mass is thoroughly compacted. In particular, a slight settlement of the downstream face need cause no concern, and the upstream face would be exposed to all conditions of weather for a considerable time before the placing of the rolled soil would get up high enough to cover the fill. All large stones should be removed from the face of the porous fill before the soil is placed against it, and during the rolling of the soil the roller should be driven as far on to the porous material as possible. It is believed that, by the exercise of reasonable care, the subsequent settlement of the rolled soil against the upstream face of the porous backing would be relatively slight, and need have no deleterious effect.

If this is not considered sufficient, a further safeguard would be possible by requiring the upstream face of the porous embankment to be rolled in layers of convenient width, building up in this way a ridge several feet high from which material for the interior could then be dumped and washed in, repeating the process with another ridge of rolled material for the next lift, and so on. While this might slow up to some extent the placing of the upstream portion of the porous fill, the natural result would be a tendency for the downstream face to be maintained at a somewhat higher level than the upstream face and the low point or pool to be nearer the latter. This would be a desirable condition from the standpoint of stability of the completed structure.

A sloping concrete core, instead of the sloping soil core above described, is another possibility, as indicated by Type No. 2. This should be of dense concrete 2 ft. or more thick, laid in blocks of convenient size, say 50 x 20 ft., with metal waterstops across all joints to permit expansion and contraction as well as adjustment to minor settlement. As an additional precaution, the concrete could be made more waterproof by painting the upstream face with coal tar or other material. Such a concrete core could probably be built more rapidly than the soil core. The porous material upstream would require no very careful compacting.

A thin vertical concrete core as an alternative would have to be placed near the center of the dam, as shown on Type No. 3. This type of core would be built in blocks with metal waterstops like the previous one. An example of this is the recently completed Priest Dam of the Hetch Hetchy project, which has a core wall 160 ft. high, 6 ft. thick on the bottom, and 2 ft. on top, built in 50 x 16-ft. blocks, with 16-gage copper strips at the joints. Some waterproofing of the upstream face of such a core is probably desirable where water-tightness is important, or a layer of rolled soil can be placed against the upstream face as is being done on the Wanaque Dam of the North Jersey District Commission. Probably 10 ft. or even less thickness of soil or of clay would be sufficient to give water-tightness in

FIG. 11. — UPSTREAM FACE OF SCITUATE DAM, JULY 23, 1926.
Showing character of riprap; water in reservoir at Elev. 268.

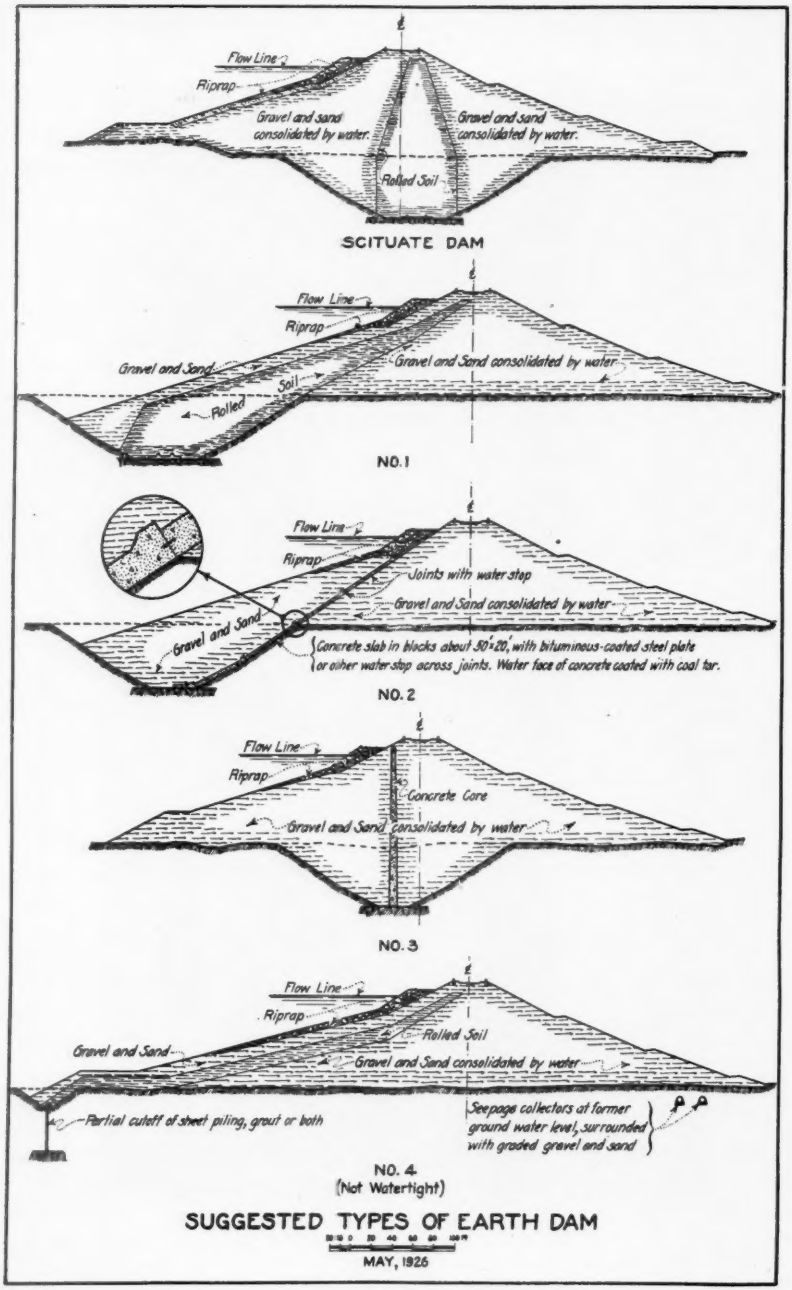

Flow Line
Riprap
Gravel and sand consolidated by water
Gravel and sand consolidated by water
Rolled Soil
SCITUATE DAM
Flow Line
Riprap
Gravel and Sand
Gravel and Sand consolidated by water
Soil
Rolled
NO. 1
Flow Line
Riprap
Joints with water stop
Gravel and Sand consolidated by water
Gravel and Sand
Concrete slab in blocks about 50'x20', with bituminous-coated steel plate or other water stop across joints. Water face of concrete coated with coal tar.
NO. 2
Flow Line
Riprap
Concrete Core
Gravel and Sand consolidated by water
NO. 3
Flow Line
Riprap
Rolled Soil
Gravel and Sand
Gravel and Sand consolidated by water
Partial cutoff of sheet piling, grout or both
See page collectors at former ground water level, surrounded with graded gravel and sand
NO. 4
(Not Watertight)
SUGGESTED TYPES OF EARTH DAM
MAY, 1926

FIG. 12.

combination with the concrete, but the practical difficulties of placing would probably lead to the adoption of a greater thickness.

Type No. 4 shows in outline a suggestion that occurred to the author last October while rereading the report of the Joint Board of 1922 on the proposed extension of sources for the Metropolitan Water District of Boston. (See JOURNAL N. E. W. W. A., June, 1922.) The outstanding feature of that report was its suggestion of trying to reduce the claims of riparian owners downstream by taking only flood flows for the Metropolitan District, allowing natural flows up to 1.2 cubic ft. per second per sq. mile to pass the point of diversion as before. For the Swift River development this would mean a daily discharge past the dam equal to at least the dry-weather flow from 186 sq. miles. Under those circumstances savings in cost and time of construction might be possible by not attempting to make the two dams of the Swift River Reservoir water-tight, so long as their safety is assured and means are provided for measuring the seepage through them.

Accordingly, the suggestion is made that for conditions such as these, if the underlying materials are not too coarse, consideration might well be given to the possibility of building an earth dam of the local porous materials but with a very broad base so as to increase the distance the water will have to travel to escape. Instead of a central core a 5- or 10-ft. layer of rolled soil could be placed over the upstream face, protected by sand, gravel, and riprap. The toe of the soil blanket might be carried down into a trench of convenient depth, from the bottom of which sheet piling could be driven to the extent practicable, and grout forced into the underlying materials.

Such a dam as this would have two or more drainage collectors of ample size somewhere in from the downstream face, say 50 ft. or more, about at the normal water level in the old river bed. The inlets to these collectors, consisting of numerous perforations in the periphery, would be protected by carefully graded gravel and sand like a filter, and a Venturi meter or a weir would provide means for measuring the seepage. The greatest care should be taken in both the design and construction of such a drainage system, to make sure that it is of ample capacity to care for all the seepage that can possibly reach it without materially raising the ground-water level downstream.

Unless the underground conditions as to porosity are materially poorer than was the case for the Scituate Dam, it is apparent that the amount of seepage through such a dam would be relatively small compared to the normal dry-weather flow of the stream. On page 350 of the JOURNAL of this Association for September, 1922, Mr. Winsor gave the record of pumpage from the core trench of the Scituate Dam. The maximum inflow was at the rate of about 6 million gal. per day from the two exposed faces of the trench, the vertical projection of each being about 1 acre, and the bottom about 70 ft. or more below the original surface. Furthermore, only a few hundred feet away from the top of the excavation the river was running in

an open channel nearly parallel with it for a thousand feet, and pools were maintained for settling basins both upstream and downstream to clarify the pumpage before it was turned into the river. The upstream pool was in the former river bed, blocked off by the toe of the dam, and the downstream pool was only about 300 ft. away from the other toe.

The main body of the embankment for such a dam as above described could be started almost immediately upon the award of the contract, and such foundation work as is required being located upstream, could be done simultaneously, thus reducing the time necessary for construction to only that required for the bulk fill. It is also believed that the saving in cost of construction would be material.

Shortly after outlining the type of dam above described, the author was interested to note an exposition of certain of the principles involved, in a paper by Dr. Charles Terzaghi, special lecturer on soil mechanics at Massachusetts Institute of Technology, printed in the Journal of the Boston Society of Civil Engineers for December, 1925 (pp. 416–22). Since then Dr. Terzaghi has assured the author that a dam of quite similar type was designed by Dr. Schaffernak, professor of hydraulic engineering at the Technical High School in Vienna, and that tests to show its feasibility were conducted at the hydraulic laboratory of the Vienna Department of Public Works and were published in *Allgemeine Bauzeitung* in 1917.

Discussion.

Frank A. Marston.* To what extent was organic matter kept out of the soil? — Were any precautions taken or was the organic matter which happened to get into the soil, just worked in with the other material?

On one of the slides showing the bank adjacent to the rolled core, it appeared that gravel and sand were being washed down, against the core material. Was there any tendency for the water to soften up the core material and form sort of a mud pie that was difficult to consolidate?

Mr. Marsh. There was quite a tendency, if it was not watched out for, for the soil to get soft and unworkable at the edge, and that had to be guarded against by rolling the soil core just as far out as possible and usually rolling a small amount of the porous material along the edge of the soil as that was rolled, in order to maintain a satisfactory condition of the soil at the edge where it joined the porous material. If the soil was thoroughly rolled before the water came against it the mud pie difficulty was not serious.

In regard to the organic matter in the soil, there was no attempt to exclude organic matter in the soil other than selecting the place where the soil was to be taken from. We did not take soil, for example, that very evidently contained a considerable quantity of muck. In certain places right close to the river where there was considerable black soil, that was not used in the soil core, but there was no attempt to rake over or exclude any material in an area which was generally acceptable.

*Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

PROVIDENCE, R. I., WATER SUPPLY — CLEARING AND GRUBBING SIX SQUARE MILES FOR SCITUATE RESERVOIR.

BY WILLIAM A. REID.*

[*Read September 16, 1926.*]

The Scituate Reservoir is situated in the town of Scituate, R. I., and is being constructed under Chapter 1278 of the Public Laws of Rhode Island, approved April 21, 1915, entitled "An Act to Furnish the City of Providence with a Supply of Pure Water." The act provides for the establishment of a Board of Commissioners known as the Water Supply Board of the City of Providence.

The work of clearing and grubbing was accomplished mainly by three parties; namely, the board's own labor force, Winston & Company, Inc., of Kingston, N. Y., and J. Livingston & Co., of New York, N. Y.

The chief work accomplished by the board's own labor force, was the clearing of the site of the regulating reservoir, located north of Danielson Pike. This work was done during the period from the middle of January to March 23, 1919, and consisted of the cutting of the brush and trees close to the ground, saving the cord wood, timber, and fence posts, and burning the remainder. Materials saved were, as far as possible, hauled outside the area flooded, generally to a highway. It had been expected that the clearing of the wet, swampy area which constituted a large portion of the reservoir, could be easily accomplished on the ice or frozen swamp, but no freezing of any account occurred during the entire winter. This made it necessary to equip the labor force for the greater part of the work with high rubber boots and necessitated their working in water, with greatly decreased efficiency, and prevented access to much of the cleared area by team and rendered the removal and disposal of the material much more difficult and expensive than would have been the case under normal winter conditions. Much material, principally brush and cord wood which had been cut but could not be removed at the time, was washed ashore as the reservoir was filling and was subsequently collected and disposed of. A yoke of oxen was used to good advantage in the extremely wet area.

The average force employed was 73 men and 3 animals; the maximum force engaged was 150 men and 7 animals. The equipment used consisted of small tools only, such as axes, cross-cut saws, garden rakes, bush hooks, and hay forks. The following is a summary of the principal work accomplished:

Number of acres on which brush and trees were cut,	108
Number of acres burned over,	93
Number of cords of wood salvaged,	250
Number of fence posts salvaged,	867
Number of logs suitable to be sawed into timber,	578

*Resident Engineer, Providence Water Supply Board.

The above work was performed at a cost to the city of Providence of $11 902.00.

The clearing, done by Winston & Company, Inc., embraced the clearing of the main reservoir area easterly of Youngs Road, between the main dam and dike and Plainfield Pike; also certain areas in other sections of the reservoir from which impervious material for the core of the dam was obtained. This work was done during the years 1921 to 1925, inclusive. The work spread over this period of time, due to the fact that this contractor was searching for material suitable for the core of the main dam and the extent of these areas was more readily determined after the brush and trees had been cut down. For this reason several areas were cut over, but only a portion of the material so cut was removed at that time, therefore requiring the removal of the balance of the material at a later date. This contract required the area to be cleared at the time of the closure of the stream-control conduit, which occurred in November, 1925. The timber was salvaged by the contractor, who conveyed it to his sawmill and there made it up into lumber. Considerable cord wood was also salvaged and used at his camp.

The total area cleared by this contractor was 947 acres, the contract price being $65 an acre, only the areas actually requiring clearing being included for payment. In addition to clearing the above-mentioned area, the necessary grubbing of the site of the main dam and dike was done by this contractor, the greater portion of this grubbing being done in conjunction with the excavation for the foundation of these structures. Steam shovels were used for this excavating. Several small areas were grubbed by hand. The total area grubbed was 9 acres.

The clearing done by J. Livingston & Co., of New York, consisted of the clearing of the entire reservoir site, with the exception of the before-mentioned areas. The work consisted of removing all perishable materials, which included buildings or portions thereof, of wood, all other wooden structures, boards, fences, trees, brush, bushes and vines, shrubs, logs, stumps standing over six inches higher than the height specified for cutting trees; loose and decayed stumps and roots, grass, weeds, leaves, sawdust, poles, planks, and other wooden parts of bridges or culverts; railroad ties, rubbish, and organic matter in dumps and elsewhere above the surface of the ground. Within the areas cleared, all vegetation was cut off as follows: trees having a diameter of 12 in. or more, at a foot above the ground, so as to leave stumps with an average height not more than 12 in. above the mean surface of the ground. All smaller trees and large bushes were cut so as to leave stumps extending not more than 6 in. above the mean surface of the ground and all other vegetation was cut close to the ground. On land which had been cultivated or on which the principal growth of vegetation was grass or weeds, with or without scattered low bushes, the time of clearing was postponed until immediately prior to the flooding of such areas or the completion of the contract, so as to avoid the necessity of reclearing.

It was found from experience that the best time to do this clearing was in conjunction with the recutting of the adjacent area. All materials cut off or removed were either salvaged or completely burned. The salvaged wood met with ready sale. The removal of the trees and brush was accomplished by hand methods; double-bitted axes and cross-cut saws were used to cut the trees; and for the bushes, double-bitted axes, bush scythes, and bush hooks were used.

Several agreements were made by the contractor with various parties, whereby upon payment of a certain sum to him (the contractor) they were allowed to go on the area to be cleared and remove any trees they desired, but in all cases fulfilling the requirements of the specifications as regards the height at which the stumps were to be left. One of these parties put in a portable steam sawmill and produced a considerable quantity of lumber, consisting mostly of pine boxwood.

Grubbing.

On the marginal strip, the trees that were to be grubbed were cut off about $3\frac{1}{2}$ ft. above the surface of the ground; the larger and more firmly rooted stumps were then dynamited. The stumps were then pulled, using a two-drum 40 h.p. gasoline-driven hoisting engine, attached to which was a $\frac{3}{4}$ in. steel cable and blocks. Three of these engines were used on the work. In addition to these engines, two grubbing parties were equipped with steel blocks and $\frac{3}{4}$ in. cable, the power being a pair of horses. The amount of work accomplished by this outfit compared favorably with that done by the engine outfit.

The grubbing required that all stumps and roots more than 2 in. in diameter within 6 in. of the surface of the ground should be removed from the marginal strip around the edge of the reservoir and around such islands as were formed therein. This marginal area included only those wooded, or formerly wooded areas, between a contour at Elev. 275, 9 ft. below the flow line of the reservoir, and a cutting line 30 ft. outside the flow line; or where the slope beyond the margin was flat, the cutting line extended to a contour at Elev. 285.5.

Chimneys, walls, and other masonry structures in mortar were broken down to the extent directed. This included large mill stacks and walls. Stone walls, chimneys, and stone foundations of buildings between Elev. 275 and the cutting line (the flow line of the reservoir is at Elev. 284), were leveled to the ground surface and the stones scattered or disposed of within the cellars. The stone walls were leveled by hand and the cellar foundation walls and chimneys were removed by dynamite. The remaining portion of the cellar was then filled with earth to the level of the surface of the adjacent ground. Cellars below the 275 contour were filled with earth to a depth of from 2 to $2\frac{1}{2}$ ft. The walls of these cellars were not required to be broken down, but this was generally done to facilitate the work of filling, the contractor using a two-horse drag scraper to do this work.

In addition to clearing and grubbing, this contract called for the construction of a pervious dike to isolate an area of shallow flowage on the margin of the regulating reservoir; also the construction of a protective fill along the shore of the regulating reservoir west of the Smithville Cemetery. The material for the pervious fill was obtained from below the flow line, the regulating reservoir having been drawn down and the water stored in the main reservoir. The excavating and placing of the material was done by means of horse-drawn drag scrapers and the material for the protective fill was obtained from a borrow pit extending along the shore of the reservoir and below the flow line. The excavating and placing of the material for this protective fill was done principally by a New England scraper, the motive power being one of the 40 h.p. gasoline-driven hoisting engines.

Other work included the removal of excrementitious material, which was removed from privy vaults, barnyards, and stables and was placed in a nearby cellar of a demolished building and completely burned. After removal of this material, the excavations were thoroughly disinfected by a liberal application of lime (hypochlorate of calcium) and then filled with earth to a depth of about 2 ft.

Prior to the time of the completion of this contract, a growth of vegetation occurred on several areas sufficient to require recutting, which was done ahead of the rising water up to Elev. 275. The area above this elevation is now being recut by the board's own labor force.

The average labor force employed was 60 men and 8 animals; the maximum average daily force in any week was 147 men and 26 animals. The following is a summary of the work done under the principal items of the contract and prices paid the contractor for same:

Clearing 2 472 acres @ $49.00 per acre.
Earth excavation 23 084 cu. yds. @ $0.50 per cu. yd.
Grubbing 539 acres @ $175.00 per acre.
Rock excavation 3 872 cu. yds. @ $3.00 per cu. yd.
Recutting 994 acres @ $18.00 per acre.
Removing excrementitious material 394 cu. yds. @ $3.00 per cu. yd.

Payment was made for clearing the entire area to be flooded, together with the marginal strip, whether or not actual clearing was necessary.

Camp.

Employees of the contractor were housed in city-owned buildings, most of these buildings being located in the basin of the reservoir. These buildings were provided with sanitary conveniences, consisting of removable cans, the contents of which were disposed of daily outside of the watershed. The contractor retained the services of a qualified physician who had the care of the employees and inspected their dwellings, making a written report to the engineer weekly.

The work on this contract covered a period from the first of January, 1924, to the end of April, 1926.

PROVIDENCE, R. I., WATER SUPPLY — REAL ESTATE AND DAMAGE SETTLEMENTS FOR 15 000 ACRES ACQUIRED FOR SCITUATE RESERVOIR.

BY EARL C. CRAIG.*

[*Read September 16, 1926.*]

The new Scituate Reservoir for the city of Providence, is located about ten miles westerly of the city, on the north branch of the Pawtuxet River, the main dam being located near the former village of Kent in the town of Scituate, at which point a drainage area of 92.8 sq. miles of watershed is tributary and a storage of about 37 billion gal. capacity has been created.

The Act under which this work was carried out was passed by the General Assembly of the State of Rhode Island early in 1915. This Act defined an area of approximately 16 000 acres which the city was permitted by law to acquire for water-supply purposes and provided for the acquirement of land and water rights necessary for the development of the new supply. Special provisions of the Water Supply Act made possible the surrender of remaining portions of farms, mill properties, etc., where property condemned was damaged or lessened in value by the taking of a part only, provided such surrenders were made within a period of one year after the property had been taken. It was also provided that damages could be recovered for lands contiguous to those taken for reservoir purposes if the latter were decreased in value by such taking, a time limit of three years after the passage of the Act being placed on such claims. Other provisions were made in the Act for damages to business or for loss of employment due to condemnation of the property. The surrender of property owned by the Ponagansett Reservoir Co., and located approximately 12 miles upstream from the Scituate Dam, was also provided for, the value of this property being affected by the construction of the Scituate Reservoir. The Act also included elaborate provisions for the regulation of the river below the dam after the storage of water was first begun, these provisions being referred to hereinafter in more detail in the section relating to water-diversion damages.

On December 6, 1916, the city of Providence condemned, under authority of the Water Supply Act, 12 547 acres of land for the Scituate Reservoir, including some land taken for new highways and cemeteries. The area finally acquired, which includes some additional property surrendered under the terms of the Act and other property acquired in connection with negotiations for settlements, will total about 15 000 acres, or nearly 23.5 sq. miles.

*Assistant Designing Engineer, Providence Water Supply Board.

At the date of condemnation a total of about 1 200 buildings of various kinds were located on the condemned area, including six cotton-mill plants, one power house and car barn, 414 dwelling-houses and bungalows, seven schoolhouses, and six churches. Within the area condemned were located the villages of Kent, South Scituate, Ashland, Saundersville, Richmond, Rockland, and Ponagansett, and portions of North Scituate and Clayville. Outside of the villages mentioned, however, the area condemned was sparsely settled, a considerable portion being wooded, brush, or pasture land, with a relatively small area only under cultivation.

Principal Settlements for Reservoir.

Settlements for properties taken for reservoir purposes included about seven important cases:*

First. The Ashland Company settlement by agreement for $195 000 in April, 1916, less than eight months prior to date of condemnation. This settlement included the purchase of an entire manufacturing property and water-power development together with about 200 acres of land, tenement houses, etc., and a cotton mill having about 20 000 sq. ft. of manufacturing floor space, with a capacity of 5 000 spindles, and about 60 employees; the purchase also including the entire machinery. A drainage area of 32 sq. miles was tributary to the water-power site, with a storage capacity at the time of purchase of about 725 million gal. and a developed head of about 18 ft.

Second. The North Scituate Cotton Mills settlement by agreement for $330 000 in October, 1916, about a month and a half prior to date of condemnation. This settlement included the entire manufacturing property and water-power development, with the exception of the textile machinery. The property obtained included about 90 acres of land, tenement houses, etc., and a cotton mill having about 60 000 sq. ft. of manufacturing floor space, with a capacity of 12 000 spindles, and about 130 employees. A drainage area of about 22.4 sq. miles was tributary to the water-power site, with a storage capacity at the time of purchase of about 725 million gal. and a developed head of about 21.5 ft. Under the terms of settlement the North Scituate Cotton Mills were allowed free rental of the property up to October, 1918.

Third. The Providence & Danielson Railway Company settlement for $200 000 in October, 1920, by agreement. About 8.5 miles of track and 28 acres of land owned by this company were located within the area condemned for water-supply purposes, the greater portion being below the flow line of the reservoir to be built. The claim made was for the value of physical property taken, which included a car barn and power station of about 700 k.w. capacity, located near the village of Rockland; and, in addition, a substantial sum was claimed for business damages on account of the elimination of mills and villages and other changes brought about by

*See Plate I for location of these properties.

condemnation. The operation of the railway west of the village of North Scituate was discontinued shortly after the settlement was made.

Fourth. The Ponagansett Reservoir Company settlement for $35 090 in September, 1922, by agreement. This reservoir, which was surrendered to the Water Supply Board in December, 1917, under the special provisions of the Act, had a storage capacity of about 890 million gal. and a drainage area of 2.1 sq. miles, located on the headwaters of the Ponagansett River about 12 miles above the Scituate Dam. The settlement included an area of about 265 acres.

Fifth. The Barden Reservoir Company settlement for $110 290 in September, 1922, by agreement. This reservoir, taken by condemnation on December 6, 1916, had a storage capacity of over 850 million gal., with a drainage area of 33 sq. miles and was used for regulating the flow of the Ponagansett River, a tributary of the north branch of the Pawtuxet River. An area of about 300 acres was included in this settlement.

Sixth. The Joslin Manufacturing Company settlement for $1 293 750 in July, 1925, by agreement, after prolonged negotiations extending over a period of several years in which a combined damage of nearly $6 250 000 was claimed by this company and the Scituate Light & Power Company (see "*Seventh*"). The property taken included the entire development of this company in Scituate and vicinity, comprising 6 distinct mill properties known as the Richmond, Rockland, Red, Upper Clayville, Lower Clayville, and Ponagansett Mills; 4 hydro-electric power developments known as the Richmond, Rockland, Clayville, and Ponagansett Power plants, together with connecting transmission lines; 2 steam-power plants located at Richmond and Rockland, respectively, and 45 tenement houses, together with appurtenant buildings and structures, storage reservoirs, mill ponds, canals, penstocks, water rights, etc. A total area of approximately 550 acres and about 135 structures of various kinds were included in this settlement. The mills proper ranged in size from about 7 000 sq. ft. to 40 000 sq. ft. of manufacturing floor space, with a total of over 170 000 sq. ft. for the entire properties owned and leased. The four hydro-electric plants taken had an installed capacity aggregating over 1 100 h.p.(820 k.w.) with net heads varying from about 10 ft. to 85 ft. and drainage areas from 4.2 sq. miles to 33 sq. miles, having storage developments of from 450 million gal. to 1 740 million gal. The two steam-power plants taken represented a combined capacity of about 260 h.p. Machinery located in the 6 mills, above referred to, including that owned in two other mills leased from the Scituate Light & Power Company, had a total combined capacity estimated at well over 100 000 spindles. This machinery was used in carrying on a braiding business in connection with other mills owned by the company and located about ten miles distant, and was taken down, moved to a new location, and re-installed, the city being obligated under the terms of the Act to pay the reasonable cost of this work. The settlement made also considered all claims made in connection with a lease referred to in paragraph

"*Seventh*" and, in addition, all questions arising as to damage done to the mills and business of this company on account of the taking of its properties; such as, for example, the possible loss of production while reëstablishing the business elsewhere, and other similar claims. Many improvements were made to these properties in the period just prior to the date of condemnation, and subsequent to condemnation other extensive improvements were made, many of which were undoubtedly the result of conditions brought about by the World War.

Seventh. The Scituate Light & Power Company settlement for $431 250 in July, 1925, by agreement (also see "*Sixth*"). The settlement included 2 mill properties known as the Shoddy and Remington Mills, and 3 mill privileges or sites known as the Upper, Middle, and Lower Saundersville privileges, the mills upon which had been destroyed by fire from ten to twenty years prior to date of condemnation; 2 hydro-electric power developments known as the Shoddy and Remington power plants, portions of the electric transmission system within the condemned area, 13 tenement houses, and a large casino, together with numerous appurtenant structures, — mill ponds, canals, water rights, etc. A total area of approximately 400 acres and 35 structures of various kinds were included in this settlement. The two mill properties (which were leased to the Joslin Manufacturing Company) had a total manufacturing floor space of about 15 000 sq. ft. The Shoddy and Remington hydro-electric power plants together represented a combined installed capacity of about 225 h.p. (170 k.w.), with net heads of about 13 and 19 ft. and drainage areas of 35.4 sq. miles and 5 sq. miles, respectively, having storage developments of 1 740 million gal. and 450 million gal. These hydro-electric plants were operated in connection with 4 other hydro-electric plants and 2 steam-power plants leased from the Joslin Manufacturing Company, so that at the date of condemnation the power company had under its control 6 power plants with an installed capacity aggregating about 1 325 h.p. (nearly 1 000 k.w.) and 2 steam-power plants with a combined capacity of about 260 h.p. for use in developing its territory. The lease referred to, under which the power plants of the Joslin Manufacturing Company were obtained, was made only three months prior to date of condemnation and was to run for a period of 40 years. Under its terms it was also provided that the Scituate Light & Power Company should furnish electric power to the Joslin Manufacturing Company for all of its mills, and that the power company should lease the Shoddy Mill and 11 tenement properties in its possession to the Joslin Company, all under stated terms and conditions. At the date of condemnation about 5 miles only of transmission lines existed and there were very few customers supplied by the power company, and little business outside of that obtained from the Joslin Manufacturing Company under the lease. Subsequent to date of condemnation, however, the transmission lines were extended throughout the town of Scituate and into the towns of Foster and Glocester, so that by the end of 1924 the commercial light and

power system included approximately 28 miles of transmission lines serving about 350 customers, most of whom were located in a territory which may be classed as rural. The settlement with the Scituate Light & Power Company, which was under the control of the Joslin interests, was affected very largely by questions as to the value of the leased properties, and as to damage to the commercial light and power business of this company by reason of interference with the supply of power and the territory available for disposal of the power, resulting from the taking by condemnation. Another important factor in this case was that the re-developments of the hydro-electric power plants and improvements of the mill properties were largely made just prior to date of condemnation, and were followed later on by other extensive improvements which were very probably the result of conditions brought about by the World War.

The following is a brief summary of the foregoing settlements:

	Settled.	Amount.
1. Ashland Company	Apr. 1916	$195 000
2. North Scituate Cotton Mills	Oct. 1916	330 000
3. Providence & Danielson Railway Co.	Oct. 1920	200 000
4. Ponagansett Reservoir Company	Sept. 1922	35 090
5. Barden Reservoir Company	Sept. 1922	110 290
6. Joslin Manufacturing Company	July, 1925	1 293 750
7. Scituate Light & Power Company	July, 1925	431 250
Total, seven principal settlements		$2 595 380

Settlements for Scituate Reservoir exclusive of Water Diversion Damages.

A general analysis of the cost of acquiring all real estate, rights and interests for the Scituate Reservoir, which included settlements for 14 660* acres, or 98 per cent. of the 15 000 acres to be ultimately obtained, indicates, that a total of about $4 100 000 was expended for this purpose. This figure includes the seven principal settlements above referred to, amounting to about $2 600 000, but does not include the cost of legal, engineering, and other miscellaneous expenses incurred in connection with the settlements. Deducting the amount expended for seven principal settlements, or $2 600 000, from the cost of acquiring the entire property, indicates that about $1 500 000, exclusive of legal, engineering, and other miscellaneous expenses, was expended in acquiring remaining lands, buildings, and improvements; a considerable portion of this property being farms, woodland or pasture land, and sparsely settled. An estimate of the proportionate part of all legal, engineering, and other miscellaneous expenses for the entire project, that is chargeable against the item of real-estate settlements, indicates that if these expenses are included, the total cost of

*This figure includes 12 400 acres, or 99 per cent. of 12 500 acres condemned, about 1 000 acres surrendered under the provisions of the Water Supply Act, and about 1 260 acres of property purchased in connection with settlements made, that was located exterior of the condemned area.

the seven principal settlements was about $2 950 000, and the total cost of the remaining lands, buildings, and improvements about $1 700 000. A further analysis indicates that the actual cost of settlement for the remaining lands, representing an area of approximately 13 000 acres, was from 2.4 to 2.7* times the assessed valuation of this property in the year 1913, or about three years prior to the date of condemnation, at which time little had been done on the project. These results were, however, affected very materially by conditions brought about by the World War and the general increase in property values and costs following thereafter.

Some idea of the character of the lands condemned for this project may be obtained from an analysis of about 2 500 acres out of 3 700 acres of land cleared and otherwise prepared for the construction of the Scituate Reservoir; these data indicating about 10 per cent. of wooded areas, 55 per cent. of brushy areas, 30 per cent. of areas such as fields, arable lands, etc., upon which little clearing was necessary, and 5 per cent. of water areas. Areas exterior of the limits of the Scituate Reservoir were very largely brush and woodland areas with a relatively smaller proportion of cleared land.

Water-Diversion Damages.

Some of the largest claims for damages in connection with the construction of the Scituate Reservoir were those made relative to water-diversion damages. The dam creating this reservoir is located on the north branch of the Pawtuxet River near the former village of Kent in the town of Scituate, approximately ten miles from the center of Providence, and has a tributary drainage area of 92.8 sq. miles from which water is to be diverted for water-supply purposes, under the terms of the Act. About 2 miles below on the stream is located the Hope Mill in the village of Hope, from which point the river flows through a series of 7 mill villages to join the south branch of the Pawtuxet and form the Pawtuxet River at a point about 5 miles below the Scituate Dam; the stream continuing on through several other mill villages and flowing into the tidewater of Narragansett Bay at a point about 15 miles below the Scituate Dam as measured along the stream. The total difference in head between the upper and lower mill privileges affected was about 180 ft., about 80 per cent. of which was developed.

The mills and privileges affected by the diversion of water were the Hope Mill and Phenix Mill, both of which were cotton mills owned at the time of settlement by the Hope Company; the Arkwright Mills and Harris Mill, comprising two cotton mills and a finishing and dye works owned by the Interlaken Mills; the Jackson Mills, Fiskeville privilege, Lippitt Mill, Natick Mill and Pontiac Bleachery, comprising three cotton mills, one bleachery, and one mill site not in use, being property then owned by B. B. & R. Knight, Incorporated; and the Clyde Bleachery & Print Works owned

*Based on total cost, including legal, engineering, and other miscellaneous expenses.

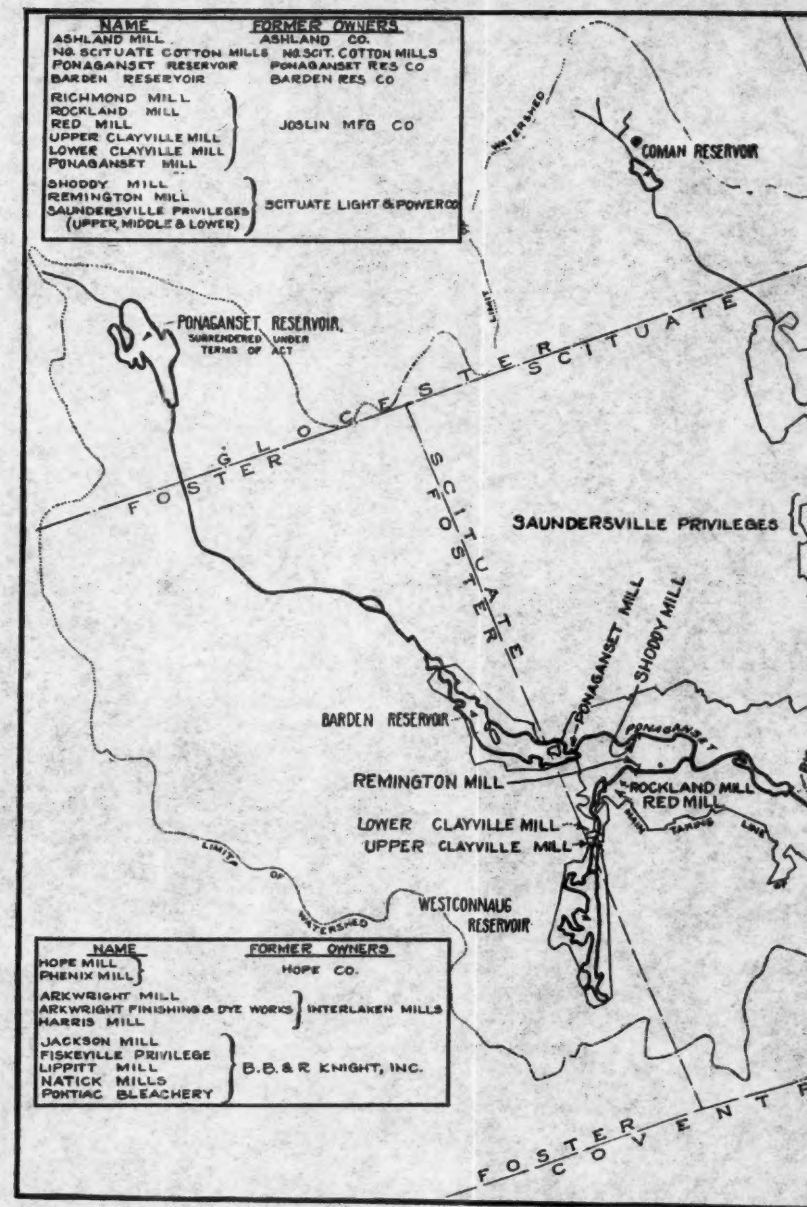
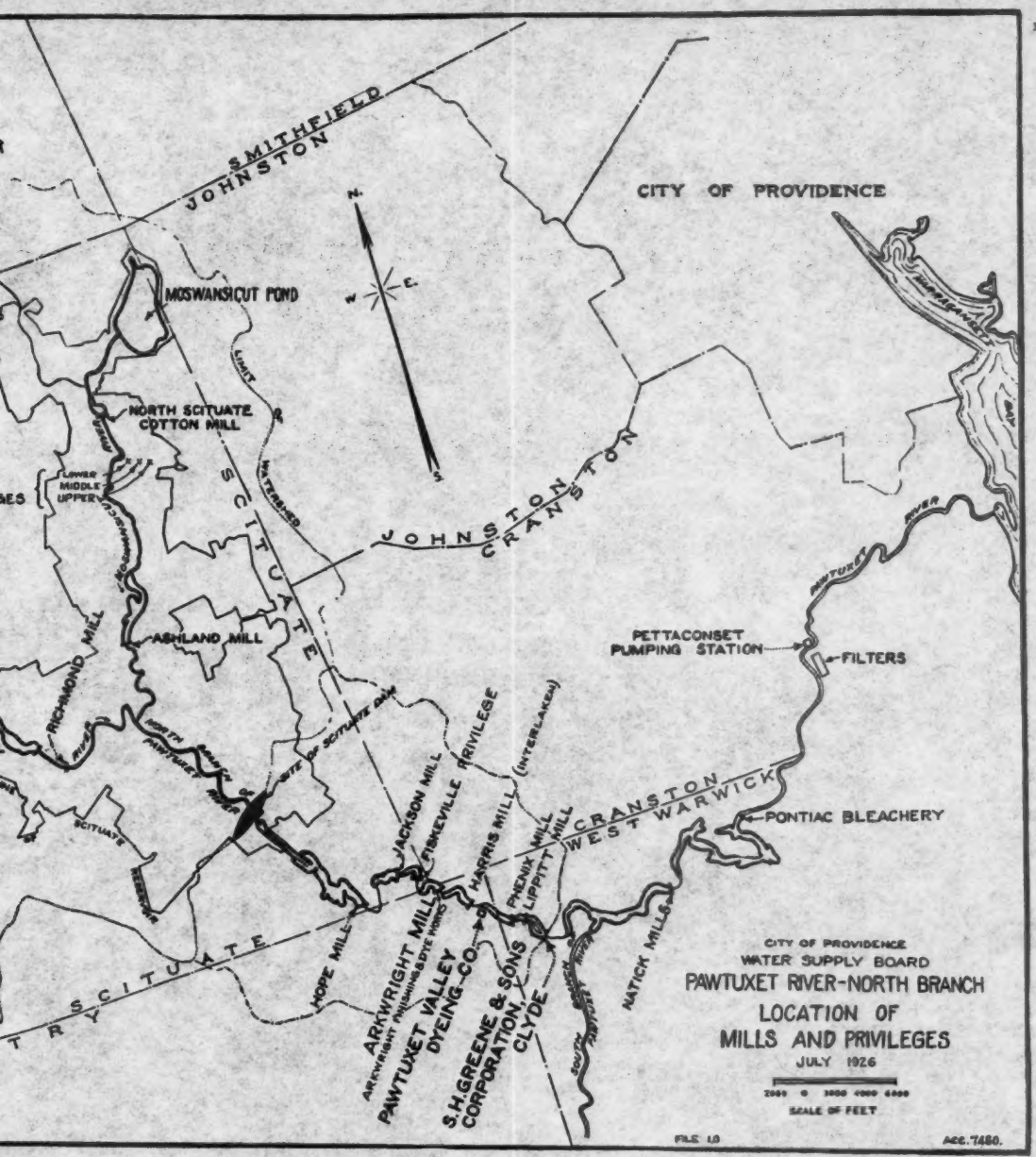

NAME
FORMER OWNERS
ASHLAND MILL
ASHLAND CO.
NO. SCITUATE COTTON MILLS
NO. SCIT. COTTON MILLS
PONAGANSET RESERVOIR
PONAGANSET RES CO
BARDEN RESERVOIR
BARDEN RES CO
RICHMOND MILL
ROCKLAND MILL
RED MILL
UPPER CLAYVILLE MILL
LOWER CLAYVILLE MILL
PONAGANSET MILL
JOSLIN MFG CO
SHODDY MILL
REMINGTON MILL
SAUNDERSVILLE PRIVILEGES (UPPER, MIDDLE & LOWER)
SCITUATE LIGHT & POWER CO
WATERSHED
COMAN RESERVOIR
LIMIT
PONAGANSET RESERVOIR.
SURRENDERED UNDER TERMS OF ACT
GLOCESTER
SCITUATE
FOSTER
SAUNDERSVILLE PRIVILEGES
SCITUATE
FOSTER
PONAGANSET MILL
SHODDY MILL
BARDEN RESERVOIR
PONAGANSET
REMINGTON MILL
ROCKLAND MILL
RED MILL
LOWER CLAYVILLE MILL
UPPER CLAYVILLE MILL
LIMIT OF WATERSHED
WESTCONNAUG RESERVOIR
NAME
FORMER OWNERS
HOPE MILL
PHENIX MILL
HOPE CO.
ARKWRIGHT MILL
ARKWRIGHT FINISHING & DYE WORKS
HARRIS MILL
INTERLAKEN MILLS
JACKSON MILL
FISKEVILLE PRIVILEGE
LIPPITT MILL
NATICK MILLS
PONTIAC BLEACHERY
B.B.&R. KNIGHT, INC.
FOSTER
COVENTRY

PLATE I.
N. E. W. W. ASSOCIATION.
VOL. XL.
CRAIG ON
PROVIDENCE, R. I.,
WATER SUPPLY —
DAMAGE SETTLEMENTS.



at the time of settlement by S. H. Green & Sons Corporation. The general relation between the Scituate Water supply development and the various mills referred to may be obtained from an inspection of Plate I.

S. H. Green & Sons Corporation Claim.

The first of the claims for water-diversion damages, that of the S. H. Green & Sons Corporation, was the suit brought in 1919, for damages to property owned by this company and located about 5 miles below the Scituate Dam. This property comprised a large bleachery and print works in active operation and included a small water-power plant equipped with a Swain water wheel, installed in 1883, having a capacity estimated at about 100 h.p. when new. The drainage area tributary to the water-power development was 106 sq. miles, 92.8 of which were to be affected by diversion. The storage on the drainage area at date of condemnation was 2 900 million gal. and a net head of about 9.3 ft. was developed. It was claimed that large quantities of water were used for bleaching and finishing purposes and that filtration of the water so used, and treatment of the water returned to the stream, had not been necessary; also that the diversion of water under the provisions of the Act would not leave sufficient water for process purposes and would impair the quality of water available for use in the future on account of the pollution resulting from concentration of wastes higher up on the stream. Included in the claim was a large item for the cost of construction, operation, and maintenance of a filtration plant to remedy these conditions. It was also claimed that the value of the water power was practically destroyed, which would require the substitution of a new source of power. The total of the claims amounted to about $2 000 000. The case was tried before a jury, the trial beginning on April 4, and ending on June 6, 1919, on which date a verdict of $334 636 was returned in favor of the company, from which both sides appealed. On May 19, 1920, the claim was settled for $265 000, by agreement. The total damages for water power and pollution, the latter being a considerable item in this case, amounted to about $307 per sq. mile per foot fall as of May, 1920.

Negotiations for the settlement of water-diversion damages for the remaining mills between the Scituate Dam and tidewater were begun early in 1918, with the Hope Company, Interlaken Mills, and B. B. & R. Knight, Incorporated, and continued more or less actively until September, 1922, when the settlements were finally completed at a total cost of $1 759 630.

Hope Company Claim.

This claim, mostly for damage to the water powers at the Hope and Phenix Mills, was settled by agreement for $395 450 in September, 1922. The drainage area tributary to the Hope Mill is 98.2 sq. miles and that tributary to the Phenix Mill 104.4 sq. miles, water being diverted from 92.8

sq. miles. The storage existing on the drainage areas at date of condemnation was about 2 900 million gal. and the net heads developed at the Hope and Phenix Mills about 23.8 ft. and 15.6 ft., respectively,— a total of 39.4 ft. for both water-power plants. The damages per sq. mile per foot fall were $108 as of September, 1922.

Interlaken Mills Claim.

The claim of the Interlaken Mills for damages to water powers at the Arkwright and Harris Mills, and for damage on account of pollution at the Arkwright Finishing & Dye Works, was settled by agreement for $581 150 in September, 1922. In addition to the claim for damage to the water powers affected, the company claimed that heavy damages would result from the smaller stream flow to be expected after diversion; the argument being, in general, that the river would become more and more affected by pollution from wastes delivered into the stream above the plant and from surface drainage, and that difficulties might develop in the dyeing processes, particularly from iron, under future conditions to be expected. As in the case of the S. H. Green & Sons Corporation claim, the necessity of constructing and operating adequate filters for purifying the water used for process purposes was stressed. An additional amount was also claimed for the treatment of wastes returned to the stream at Arkwright. The drainage area tributary to the Arkwright Mill was 102.2 sq. miles and that tributary to Harris Mill 102.9 sq. miles, water being diverted from 92.8 sq. miles. Storage on the drainage areas at the date of condemnation was about 2 900 million gal. and the net heads developed at the Arkwright and Harris Mills about 18.0 ft. and 18.5 ft., respectively,— a total of 36.5 ft. for both water powers. The combined damages per sq. mile per foot fall were about $177 as of September, 1922.

B. B. & R. Knight, Incorporated, Claim.

This claim for damage to water powers at the Jackson, Lippitt, and Natick Mills, the Pontiac Bleachery, and a water-power site at Fiskeville, — the former power development of which had for some time been in ruins, — was settled by agreement for $783 030 in September, 1922, the settlement price also including a considerable amount claimed for pollution damage at the Pontiac Bleachery. The drainage areas tributary to the water-power privileges were as follows: at Jackson Mill 100.4 sq. miles, at Fiskeville privilege 101.8 sq. miles, at Lippitt Mill 104.4 sq. miles, at Natick Mills 180.1 sq. miles, and at Pontiac Bleachery 196.3 sq. miles, the south branch of the Pawtuxet River being also tributary to the two latter privileges. In each case the diversion of water was from 92.8 sq. miles only. Storage on the drainage areas at date of condemnation totaled about 2 900 million gal. for all privileges except those at Natick and Pontiac, the latter having about 5 900 million gal. The net head developed at Jackson Mill was

about 12.1 ft., at Fiskeville privilege 0 ft., at Lippitt Mill 14.9 ft., at Natick Mills 21.3 ft., and at Pontiac Bleachery 6.0 ft., or a total of 54.3 ft. for the group. The combined damages per sq. mile per foot fall were about $155 as of September, 1922. As in the other cases, it was claimed that the diversion of water under the terms of the Act damaged the water powers on the south branch considerably, and practically destroyed the value of those on the north branch of the Pawtuxet, and in the case of the Pontiac Bleachery would cause heavy damages on account of the pollution of the stream resulting from the concentration of mill wastes, which would necessitate filtration of the process water at times.

The following is a brief summary of the settlements for water-diversion damages:

	Settled.	Amount.
1. S. H. Green & Sons Corporation	May, 1920	$265 000
2. Hope Company	Sept. 1922	395 450
3. Interlaken Mills	Sept. 1922	581 150
4. B. B. & R. Knight, Inc.	Sept. 1922	783 030
Total		$2 024 630

An estimate of the proportionate part of all legal, engineering, and other miscellaneous expenses for the entire project, that is chargeable to the settlements for water-diversion damages, indicates that, if these expenses are included, the total expenditure for the diversion of water was about $2 300 000.

The total paid for about 15 000 acres acquired for Scituate Reservoir, including the amount paid in settlement of the water-diversion claims, was about $6 125 000. If legal, engineering, and the miscellaneous expenses are included, this figure becomes about $6 950 000.

The Water Supply Act under which the city of Providence was authorized to acquire waters and water rights on the north branch of the Pawtuxet River, provided for many requirements and limitations relative to the diversion of water and regulation of the stream after the storage of water was begun. No water was to be diverted until the reservoir was ready for use, and from the time when the city first began to store water until when 20 billion gal. were stored for the first time, it was provided that the city should not reduce the flow below the dam on any week day below the natural stream flow unless the latter exceeded 20 million gal. daily, in which case the city was permitted to store the excess water. After 20 billion gal. of water had been stored for the first time, it was provided that the city must draw a quantity of water from the reservoir each month equivalent to not less than 70 million gal. daily, and that all of this quantity not used for water-supply purposes should be discharged into the river below the dam, the water to be regulated with respect to the hours and the quantities discharged to meet, so far as practical, the requirements of bleacheries,

finishing or dye works, and other mills located below on the stream. It was also provided that the basic draft of 70 million gal. daily could be reduced to 65 million gal. daily in any year in which the reservoir did not fill by the first of June.

Other requirements were that the city must discharge at least 500 000 gal. of water each day into the river below the dam and, in addition, such further quantities of water and at such times as necessary, in order to maintain a flow into the Arkwright Mill pond of not less than 6 million gal. daily, except Sundays; and such further quantity of water and at such times as necessary, to maintain a flow into Clyde Mill pond of such quantity, not exceeding 72 million gal. each week, as the owners of this privilege should certify as necessary for manufacturing purposes other than the production of water power. The Arkwright and Clyde Mill ponds, referred to, were located about 3 miles and 5 miles, respectively, below the Scituate Reservoir, at which points the drainage area intervening between the mill ponds and the Scituate Reservoir were 9.4 sq. miles and 13.2 sq. miles, respectively.

The city was further required to establish and maintain proper gaging stations at or near Arkwright and Clyde for the purpose of ascertaining the stream flow at these locations and to furnish, upon request, information to the mill owners regarding regulation of the stream flow, drafts from the reservoir, etc.

Under the terms of the Act relative to diversion of water and regulation of the stream flow, it was claimed by the city that a progressive taking of the water had been made, since it was practically inconceivable that the city would need the entire 70 million gal. daily basic draft required under the Act until some years hence, and since the city was furthermore under obligation to deliver that portion of the water not used for water-supply purposes into the river below the dam for the benefit and use of the mill owners. Attention was also directed to the fact that under the terms of the Act the city could not divert water until the Scituate Reservoir was ready for use, under which condition it was estimated that actual diversion of the waters would not begin before the summer of 1925, or even later. The mill owners, however, claimed that, while it was possible that the entire 70 million gal. daily basic draft might not be used at once by the city, nothing contained in the Act prevented the city from utilizing the entire quantity for water-supply purposes much sooner than was anticipated and that, consequently, the only stream flow which could be definitely relied upon was the 6 million gal. flow each week day into Arkwright Mill pond or an amount possibly as great as 72 million gal. weekly into Clyde Mill pond, if the latter quantity was certified to be required by the owner of the latter privilege.

Under these circumstances, with the relatively small quantities of water which they claimed could be definitely depended upon, practically all of the water power of the stream was considered as taken except on the south branch, and correspondingly heavy damages on account of pollution were

claimed, particularly by the Interlaken Mills which depended solely upon the flow of the north branch of the Pawtuxet for their supply of process water. The difficulties surrounding the settlement were finally overcome, however, and a contract made under date of September 1, 1922, between the Hope Company, B. B. & R. Knight, Incorporated, Interlaken Mills, and the city of Providence, by means of which the settlements previously referred to were accomplished.

Under the terms of this contract the city could not hold back water until the Scituate Reservoir was ready for use, in no event before May 1, 1925, and agreed to permit, so far as possible, the mill owners or reservoir companies to operate and control the Barden and Ponagansett reservoirs (located on the watershed above Scituate Dam) until May 1, 1925. While storing the first 20 billion gal. of water in the Scituate Reservoir the city agreed to discharge into Hope Mill Pond at least 20 million gal. daily, except Sundays, or such quantity as the stream flow, augmented by the available storage in certain of the storage reservoirs on the watershed, would permit, the water to be drawn from such available levels as would furnish a quality most suitable for bleacheries, finishing, or dye works. During the storage of the first 20 billion gal. the city also agreed to maintain a flow into Clyde Mill Pond of at least 12 million gal. each week day, except Sunday, unless the natural stream flow, together with the flow from storage, made this impossible.

No water was to be diverted from the drainage area until the first 20 billion gal. were stored, after which time the city guaranteed to discharge from the Scituate Reservoir into Hope Mill Pond at least the following quantities of water:

From date of storage of first 20 billion gal. until 1927, 36 million gal. daily; during 1927, 36 million gal. daily; during 1928, 40 million gal. daily; and thereafter a quantity diminishing year by year so that in 1930, 38.5 million gal. daily were to be released; in 1940, 28 million gal. daily and in 1950, 15.5 million gal. daily; the agreement ending in 1955 with a required draft of 9 million gal. daily.

The city was required to concentrate the flows above referred to in a reasonable manner, so far as practical, if requested in writing by the mills, the flows to be regulated especially to meet the requirements of those operating bleacheries, finishing or dye works, to the extent consistent with the rights of other parties under the Act. It was further required that after the first 20 billion gal. were stored, at least 12 million gal. daily flow each week day, except Sundays, must be maintained at Clyde, the mills agreeing not to unreasonably detain or use the water if such action interfered with the maintenance of this stream flow by the city. Other provisions of the contract rendered it possible for the city to divert portions of the guaranteed flows in emergencies, in which case elaborate provisions were made for the replacement of power, if any was lost under these circumstances. It was also agreed that the city would not impair the suita-

bility of the stream for use at bleacheries, finishing and dye works, by the discharge of wastes into the stream, and that after the storage of the first 20 billion gal., water should be drawn from the upper intake of the main gate-house between elevations from 24 to 32 ft. below the flow line of the Scituate Reservoir when filled; or if the water is lower than 24 ft. below the flow line, then from the intermediate intake, the openings of which are from 44 to 49 ft. below the flow line of the reservoir. Another section of the contract provided that the city should establish and maintain, at its own expense, proper gaging and testing stations to determine the quantity and quality of the water discharged into the river from the Scituate Reservoir or from any purification works, the data to be furnished the mills upon request. Provision was also made for the settlement of possible disputes over the terms of the contract by arbitration.

The water wheels in use in the mills owned by the three companies were practically all of the type known as "Hercules," with installation dates running from 1883 up to 1909. The total installed capacity of water-power equipment affected by the diversion of water was, in the case of the S. H. Green & Sons Corporation, about 100 h.p. (if new), with a development of 1.3 cubic ft. per second per sq. mile of watershed; for the Hope Company about 900 h.p. for two sites, with developments ranging from 2.5 to 2.8 c.f.s. per sq. mile of watershed; for the Interlaken Mills about 500 h.p. for two sites, with developments ranging from 1.5 to 1.7 c.f.s. per sq. mile of watershed; for B. B. & R. Knight, Incorporated, about 3 000 h.p. for four sites, with developments of 1.5, 1.7, 2.6, and in one case as high as 6.8 c.f.s. per sq. mile of tributary watershed. The combined capacity of water-power equipment for the four companies was about 4 500 h.p., and the power diverted was estimated to average about 2 100 h.p. yearly, on the basis of the existing developments.

Rainfall and Run-off from Scituate Watershed.

A record of the rainfall and run-off of the north branch of the Pawtuxet River at Fiskeville, from a watershed of 101.8 sq. miles, has been obtained by the Water Supply Board since 1916, the data proving to be of great value for use in the settlement of the claims for water-diversion damages. This record shows for the Scituate watershed an average yearly rainfall of 47.96 in. and run-off from land areas only of 27.58 in., or 57.5 per cent., for the 10-year period 1916–1925. On the Wachusett watershed for the corresponding 10-year period, the average yearly rainfall was 44.96 in. and run-off from land areas only, 25.64 in., or 57 per cent. For the 29-year long-term record on the Wachusett watershed the average yearly rainfall was 45.24 in. and run-off from land areas only, 24.16 in., or 53.4 per cent. The data so far obtained indicate that there is about the same relative amount of run-off from the Scituate and Wachusett watersheds. An estimate of the long-term average yearly rainfall on the Scituate watershed

indicates that this figure is probably about 46 in., which compares with a long-term average of 45.24 in. for the Wachusett watershed.

An inspection of the 10-year record for the Scituate watershed shows that the yearly rainfall has varied between 39.15 in. (in 1924) and 56.42 in. (in 1919); the run-off between 19.04 in. (in 1925) and 33.32 in. (in 1922); and the per cent. of rainfall collected, between 42.9 per cent. (in 1925) and 66.4 per cent. (in 1916). Two very dry periods were experienced during the record, the first in 1924 when the run-off for five months, from July to November, totaled only 2.38 in., and the second in 1925 when the run-off for five months, from June to October, totaled 2.42 in., an average of about .48 in. per month for both periods. The maximum rate of discharge observed from this watershed during the 10-year record occurred during the storm of September, 1922, when a peak of 28 cubic ft. per second per sq. mile was reached at Fiskeville.

A daily duration curve of the north branch of the Pawtuxet River at Fiskeville, for the ten calendar years 1916–1925, inclusive, is shown on the accompanying diagram (Fig. 1) together with the enveloping curves for high and low points of the records for individual years.

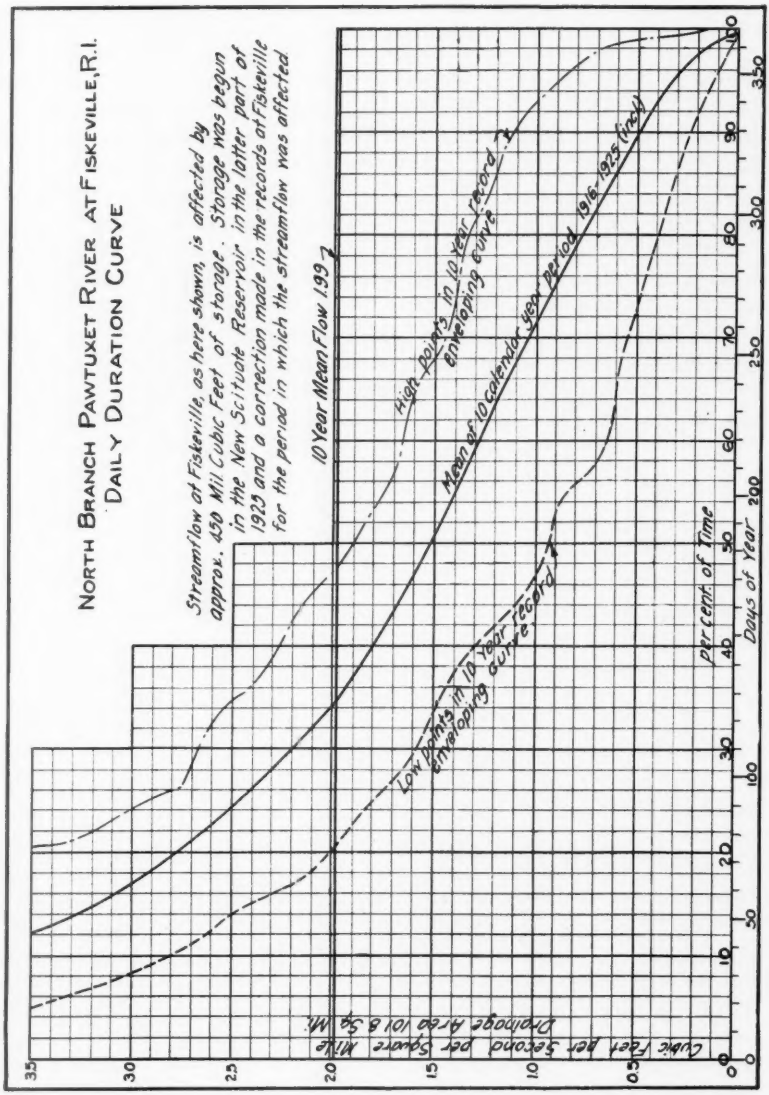

North Branch Pawtuxet River at Fiskeville, R.I.
Daily Duration Curve
Streamflow at Fiskeville, as here shown, is affected by approx. 450 Mil Cubic Feet of storage. Storage was begun in the New Scituate Reservoir in the latter part of 1923 and a correction made in the records at Fiskeville for the period in which the streamflow was affected
10 Year Mean Flow 1.99 ?
High points in 10 year record ? enveloping curve
Mean of 10 calendar year period 1916-1925 (incl)
Low points in 10 year record ? enveloping curve
Cubic Feet per Second per Square Mile
Drainage Area 101.8 Sq. Mi.
Per cent of Time
Days of Year

FIG. 1.

PROVIDENCE, R. I., WATER SUPPLY — SOME DETAILS OF GROUTING AND PREPARING THE FOUNDATION OF SCITUATE DAM.

BY JAMES V. TURNER.*

[*Read September 16, 1926.*]

The Scituate Dam is an earth structure 3 200 ft. long, 100 ft. above the original surface, and 180 ft. above the ledge rock at its maximum section. The core is of soil stripped from the reservoir basin. The core starts from the ledge rock for the entire length of the dam. The foundation for the core was so treated that the rock was sealed underneath the core and probably for a minimum depth of at least 20 ft.

The treatment of the foundation consisted of the excavation of the unsound ledge rock, the drilling of grout holes, the placing of a concrete blanket, and the sealing of the ledge rock with liquid grout under light pressure.

The overburden was a glacial drift of sand and gravel containing about 4 per cent. of boulders larger than one-half cubic yard. This material was excavated and used to form part of the ballast which makes the pervious portion of the dam. The ledge rock was a gneissoid granite, commonly called a bastard granite, and was very hard and in general rather tight.

The treatment was carried on in short sections generally about 150 ft. long. After the overburden had been cleaned off, the first step was to remove all of the loose, detached or disintegrated rock as well as sound rock which projected above the general plane but which was separated by wide horizontal seams.

No explosives were used in this excavation. Wedges were driven in the seams with heavy hammers, and 250-pound pinch bars 12 ft. long were used to pry the rock loose. These heavy bars were worked up and down by four or five men and were very effective. Sometimes two of these bars were placed a few feet apart in a seam and a loaded skip dropped on the upper end. If the rock was very seamy, one man could remove considerable rock with an ordinary crowbar. Hitting the rock with a heavy hammer would indicate whether the rock was sound. A ringing noise indicated sound rock and the slabs gave off a hollow sound. After a slab had been loosened it could be broken up in pieces small enough to handle by using dynamite. Where the rock was very tight and slabs heavy a row of small holes and plugs and feathers was perhaps the most effective and quickest way of excavating.

*Resident Engineer, Water Supply Board, Providence, R. I.

After the rock was loosened it was rolled into two yard-skips and hoisted out of the trench by a derrick.

It was found that after wedges had been driven in very tight sections it was a good plan to pour in a little water, for the combination of the atmosphere and water appeared to loosen the rock so that the next day the blocks almost seemed to roll out of their own accord. This class of work required a picked gang of strong men and everlasting perseverance.

The rock was then washed and swept off, but after a few days' exposure to the atmosphere there was generally a small amount of scaling to be done of thin slabs about $\frac{1}{2}$ in. thick.

After sound rock had been obtained, grout holes, approximately 20 ft. deep and 15 ft. apart, were drilled. These holes were staggered about 15 ft. on either side of the center of the trench. Each hole was felt out to locate horizontal seams with a half-inch pipe with a flattened-out projection $\frac{3}{4}$ in. long on the end. By moving this feeler up and down the sides of the hole all seams from $\frac{1}{4}$ in. up could be located. This survey was plotted in profile and the extent of large seams determined. In very seamy rock colored water was pumped in one hole to determine the extent of communication between holes.

Short pieces of 2-in. pipe were placed in each grout hole, threaded at the upper end for connection to the grouting machine. These pipes were made tight by caulking with oakum, then wedging the pipes in the drill holes to prevent movement and building a cookie of concrete about 18 in. in diameter and 6 in. above the rock. Pairs of vent pipes were placed at seams which appeared as though they might not be reached by the grout from the drilled holes.

The holes were drilled with the Water Lyner type of tripod machine operated by air. Water was forced through the hollow steel so that the particles of pulverized rock were washed away and the hole kept free at all times. This type of drill is superior to the old-fashioned piston drill where the steel is lifted up and allowed to fall as the drills generally become wedged at inclined seams. The Water Lyner drills are not lifted from the bottom of the hole but are turned and forced down by an air hammer which taps the top of the drill.

After the holes were drilled, a concrete blanket was placed over the rock. The blanket was generally in the middle of the trench and about 30 ft. wide and 1 ft. thick. Near each edge of this blanket a small cut-off wall was placed. These walls were about 2 ft. high.

Where the rock was very uneven the depth of blanket was varied and in places was 5 or 6 ft. In places where it was thought that considerable grout might be lost on account of horizontal seams the blanket was carried all the way across the trench. The purpose of the blanket was to confine the grout in the rock and also to smooth out the irregularities and make an easier and surer bond between the masonry and the soil core. At places where the rock was smooth and sound no blanket at all was placed but the

small cut-off walls were carried continuously from one end of the dam to the other.

A 1-3-5 mixture of concrete was used in this work. Forms were rather rough and the surface was not smoothed, as it was considered that an unfinished surface would give a better bond with the soil core.

Grout.

After the concrete blanket had been placed on the rock the grouting operation was started. Generally this operation began at the low point and progressed uphill. Before grouting, the holes were blown out with water and air. A small pipe, long enough to reach to the bottom of the holes, was connected with the grout machine, the tank filled with water, and then about 100 lbs. of air turned on at the tank and suddenly released so that any dirt or pulverized stone in the grout holes was blown out. After all the holes in the section were cleaned, a very thin liquid grout was forced into the holes under light pressure of not more than 10 lbs. to the square inch.

The grouting machine consisted of a tank holding a quarter yard when full, with paddles connected to a horizontal shaft, which was operated by a 3-cylinder air engine. The operation of grouting consisted of starting at one hole and forcing grout in to refusal, then proceeding to the next hole and doing the same, the vent pipes being considered as holes and connected and grouted in their regular order. The mixture used was generally one part of cement to ten parts of water, although when grout was coming out freely through seams the mixture was thickened to 1 part of cement to 5 parts of water.

Instances where the rock looked perfectly sound have shown numerous hair cracks out of which came air bubbles and small amount of grout at the start of this work and then became sealed. There is no doubt that this same change went on below the surface where it could not be seen. In many instances grout holes were filled with water which was under pressure and came to the top of the pipes and ran out over the rock. After grouting, the pipes would become filled with cement, the flow of water would be completely stopped, and the section would become dry. No large amount of grout was lost through open seams, although there were several cases where considerable persistence was required before a section became completely sealed. Where grout came freely through a seam, sand bags were placed to form a dam and a small reservoir and settling basin made where the cement settled to the bottom and the water ran away over the top of the dam. A small amount of sand thrown into this basin gave the cement something to become attached to and form a concrete covering to these seams.

When a section was ready for grouting, the operation was carried on continuously both day and night, as a delay for even a few hours might

cause the bottom of some of the grout holes to become filled with cement before the seams in the adjacent rock were sealed.

The following is a description of the movements used in operating the grout machine. The machine is set up level on a platform and connected to an air line and a water line. The air was furnished by an Ingersoll-Rand Compressor which was capable of delivering 200 cu. ft. of air per minute. The air is turned through a 1-in. pipe which leads to a 3-cylinder air engine which is run continuously and operates several paddles of the tank which keeps the cement and water agitated at all times. Then the water is turned on and the tank filled to the desired level, generally about half-full, and the cement added through a square opening at the top of the machine. The gate at the top of the machine is a flap valve which is pulled up tight and held in place by the air pressure which enters through a $\frac{1}{2}$-in. valve. The pressure is brought to 10 lbs. as indicated on an air gage at one end of the machine. At this pressure, a 2-in. stopcock is opened and the mixture allowed to discharge from the machine through pipes to the grout holes. The air is kept at the required pressure by leaving the air valves slightly open until all the grout has been forced into the holes. This is determined by means of a 2-in. valve at the end of the discharge line just beyond the connection with the grout holes. The valve at the end of the line is continually opened, at least once a minute, and as long as grout discharges here we know that the tank is not empty. This valve also allows any accumulation of air to escape so that grout free from air is being forced into the holes. When this valve is opened and nothing but air comes out it is a sign that the grout has been entirely discharged. While renewing the charge in the tank, the pipe line is closed at the outlet to the machine and the valve at the end of the line left open. When this second charge is released from the machine, the valve at the end of the line is kept open to release any air in the line and, when nothing but grout comes out, this valve is closed and operated as before. The object is to force grout with as little air as possible in it into the rock.

After the first grouting was completed, test holes, 30 ft. deep and about 100 ft. apart, were drilled in every section and these holes grouted in the usual way. The test holes took a very small amount of grout, so we feel confident that the first grouting was in all cases effective.

The average amount of grout used was 0.93 cu. yd. per lin. ft. the maximum per lin. ft. was 7.45, and minimum per section treated was 0.27 cu. yd. The stream control conduit runs normal to the axis of the dam about one third of the distance from the westerly end, and a rock cut about 10 ft. deep and 60 ft. wide was necessary for this concrete conduit. The usual methods of rock excavation by blasting were employed here, and while all the loose rock was removed, the gases from the dynamite had penetrated the seams and opened them up so that a very unusual amount of grout was necessary to seal the rock in this section.

The work described consisted of the treatment of about 192 000 sq. ft. of ledge rock at a cost of about 74 cents per sq. ft.

Two hundred and eighty-five grout holes were drilled for a total length of 5 204 ft., which means about 0.027 lin. ft. of hole per sq. ft. of rock treated.

There was a total of 3 160 cu. yds. of grout used, or about 0.017 cu. yd. per sq. ft. of rock treated.

Approximately 10 000 barrels of cement were used in the concrete and the grout.

The costs for this work under Contract 8 with Winston and Company, Inc., of Kingston, N. Y., were: rock excavation, $5.90 per cu. yd.; drilling holes, $0.70 per lin. ft.; grout, $5.80 per cu. yd.; concrete, $7.20 per cu. yd.; and Portland cement, $3.00 a barrel.

PROVIDENCE, R. I., WATER SUPPLY—PURIFICATION WORKS.

BY WALTER W. KITTREDGE.*

[*Read September 16, 1926.*]

The Purification Plant which forms a part of the new Scituate Water Supply for the city of Providence, R. I., is located about a mile from the gate house of the Scituate Reservoir. It is a rapid sand type of plant with a present capacity of 50 m.g.d. The water conduits, basins, pumps, tanks, etc., are designed for a 100 m.g.d. plant. The operating level of the filters is 29 ft. below the flow line of the Scituate Reservoir. This gives an available storage of 23 billion gal.

The raw water will be taken directly from the Scituate Reservoir. No appreciable quantity of sediment should remain in the water by the time it is drawn from the reservoir; in fact, there is very little sediment in most of the streams feeding the reservoir. Many of these streams drain swamps and wooded areas and the raw water is expected to have considerable color. Samples taken daily show a range of from 23 to 78.

The present filter plant is the slow sand type and satisfactorily treats water taken from the same river at a point farther downstream, but is at too low an elevation to be used in a gravity system and will be abandoned. For some time it was an open question whether the new plant should be the slow sand type or the rapid sand type. The rapid sand type was decided upon partly because of the contour of the region and the materials encountered. The site available by location and elevation is so rolling that a major grading job would be necessary to prepare an area for a slow sand filter plant. Part of the area is swampy and the proportion of boulders over $\frac{1}{2}$ cu. yd. in volume has averaged five and one-half per cent. in the area excavated. Consequently, foundation conditions were not favorable for an extensive structure, and excavation and disposal costs would have been relatively high. Another important factor leading to the adoption of rapid filters is the necessity of color reduction, since the raw water will at times be so highly colored as to render suitable decolorization by slow sand filters of the usual types impossible.

The essential parts of the plant and the system of treating and operating are as follows:

The raw water is received at the plant at the influent control chamber at whatever head is available. Coagulant is added and the water flows to the influent aerator, or *vice versa*, as may prove best in operation, provision having been made for introducing the coagulant either before or after aerating. Provision is also made in the influent control chamber for by-pass-

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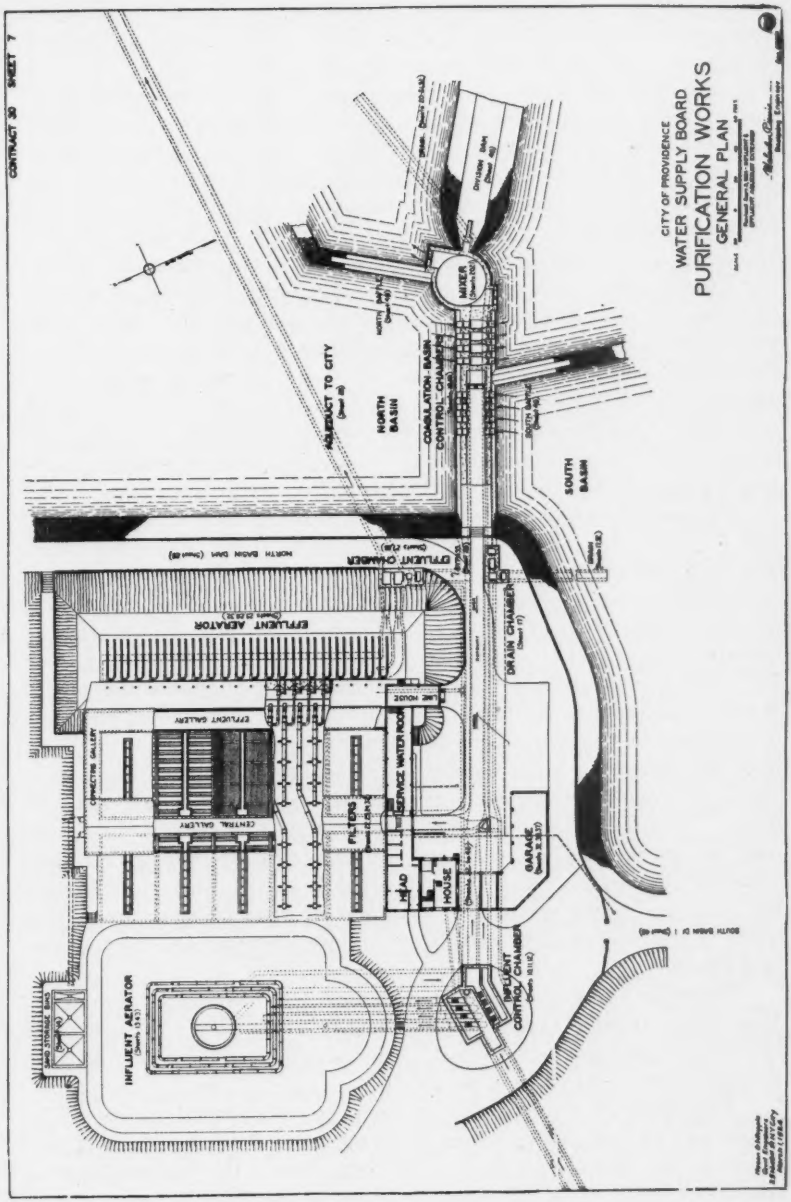
CONTRACT 30 SHEET 7
CITY OF PROVIDENCE
WATER SUPPLY BOARD
PURIFICATION WORKS
GENERAL PLAN
AQUEDUCT TO CITY
NORTH BASIN
SOUTH BASIN
MIXER
COAGULATION BASIN CONTROL CHAMBER
EFFLUENT CHAMBER
EFFLUENT AERATOR
DRAIN CHAMBER
INFLUENT AERATOR
INFLUENT CONTROL CHAMBER
FILTERS
SERVICE WATER ROOM
GARAGE
HOUSE
CENTRAL GALLERY
EFFLUENT GALLERY
CONNECTING GALLERY

ing the aerator. After aeration the water returns to the influent control chamber and flows through a 72-in. by 36-in. Venturi meter. A second meter is provided but is closed by a sluice gate until the draft on the plant is greater than one meter can accommodate. These meters are built of concrete with cast-iron pressure rings. Beyond the meters is the so-called main structure. This structure consists of two conduits placed one above the other. The lower one conveys incoming water from the influent control chamber to the mixer and the coagulation basins. The upper one takes water from the coagulation basins to the filters. The main structure also serves as a portion of the dam separating the two coagulation basins.

At the far end of the main structure is the mixer. The mixer is a circular tank without baffles, 35 ft. in diameter and about 30 ft. deep. The lower conduit of the main structure discharges into the mixer through a constricted opening near the bottom. This opening may be adjusted by planks to obtain the proper velocity. The relative position of the opening to the side of the mixer is such that the water is directed in a circular flow around the circumference, gradually rising until it flows through gates near the top out into the coagulation basins.

The coagulation basins are formed by building dams across the open side of a broad, flat valley. A dam from the mixer to the back of the valley divides it into two basins. In each basin there is an earth and rock embankment serving as a baffle. One basin has a capacity of 94 million gal., the other a capacity of 31 million gal. The basins are cleared of vegetation but are not stripped of topsoil. The margins are grubbed down to five feet below operating level. No other treatment of the basins was made. Water is delivered to the basins through the mixer, gates being provided in the mixer by which the water is directed to the basin desired. Passing from the mixer the water circulates around the earth baffle and enters the upper conduit of the main structure through which it passes to the filters. If an extremely long period of circulation is desired, the basins may be used in series, gates through the main structure having been provided for this purpose. As an opposite extreme, a cross-connection between the lower and upper conduits of the main structure will permit sending water to the filters without passing it through the mixer and the coagulation basins.

There are ten filter units, each with a net filtering area of 1 638 sq. ft. Each unit is rated at approximately 5 m.g.d. This gives a filtration rate of 125 million gal. per acre per day. Control apparatus is specified to have a range of from 2 to 7 m.g.d. per filter.

The filters are arranged five on each side of a central gallery. The upper part of this gallery serves as an operating floor, for washing and observing the filters. Below this operating floor is the conduit bringing coagulated water from the main structure to the filters. Below this is another conduit which carries away the waste wash water. Each filter is served by one influent gate and one waste wash-water gate. Each filter

is divided into two equal parts by a channel collecting the waste wash water from the wash-water gutters and conducting it to the drain. Each half of the filter has an independent collecting system. This collecting system is also connected to the wash-water pipe and serves for distributing the wash water. Each collector system consists of a main cast-iron pipe line laid below the filter floor. This main pipe varies from 20 in. up to 30 in. in diameter and has four sets of 12-in. connections branching from each side and turning up through the floor. At the floor level the lines again branch like a tee into a manifold which is drilled and tapped to receive the laterals. The laterals, or collectors, are 3-in. cast-iron pipe drilled with eight $\frac{1}{2}$-in. holes spaced at approximately 10 in. Laterals are spaced at about $8\frac{3}{4}$ in. The holes in the laterals are turned to the floor, thus promoting a more even distribution of wash water and tending to keep all sand out of the laterals when filtering.

The filter underdrains, the laterals, and the alum solution pipes are lined with a mixture of neat Portland and Rosendale cement. The thickness of the lining averages $\frac{1}{8}$ in. in the laterals and $\frac{1}{4}$ in the other pipe.

The gravel for the filters consists of one 6-in. layer of coarse gravel and four 3-in. layers of smaller sizes, the range being from 2 in. at the bottom to 12 mesh at the top. On the top of the gravel there is 30 in. of sand. Thus there is a total of 4 ft. in depth of gravel and sand. The top of the sand is 24 in. below the top of the wash-water gutters. The gutters are made of concrete 4 in. thick and have an inside width of 24 in. The overall width of the gutter is 32 in. and the clear distance between the gutters is 34 in. The operating level of the water is 6 ft. 3 in. over the top of the sand.

The collector pipes pass from under the filter boxes into a pipe gallery containing the main 48-in. wash-water pipe, the wash water, effluent, and waste effluent valves, and the control and indicating apparatus. From the effluent pipe gallery the filtered water pipes pass to the effluent aerator. The maximum flow line of this aerator is 10 ft. below the operating level of the filters. The aerator consists of 20 fixed spray nozzles and one large variable flood nozzle for each half filter. The fixed nozzles are designed to care for the complete discharge of a clean filter. As the filter gradually becomes dirty the loss of head will increase. Consequently under the reducing head the capacity of the fixed nozzles decreases. As this occurs the variable nozzle is opened the proper amount to allow a sufficient flood of water to flow through it to maintain the desired total quantity. The variable controller nozzle is essentially a cone mounted on the upper end of a vertical shaft and closing a circular orifice in the top of the effluent line but offering no obstruction to the flow in the pipe. The cone is pushed up from its seat to the proper height by a hydraulic cylinder mounted on the lower end of the shaft inside the pipe gallery. The mechanism controlling the nozzle consists of a standard Venturi tube placed in the effluent line and connected to a balanced diaphragm which is in turn linked to a

pilot valve feeding water to the hydraulic cylinder under the controller nozzle. The diaphragm is balanced by movable weights which are set for the desired rate of flow. As the rate decreases through increasing loss of head the pressure on the diaphragm becomes unbalanced and the pilot valve is open to admit water to the hydraulic cylinder of the controller. When the controller is opened sufficiently to attain the proper rate the pressure on the diaphragm is again balanced and the pilot valve resumes a neutral position.

As an alternative to aerating the effluent, a by-pass is provided which discharges directly into the pure-water conduit under the effluent aerator. The by-pass consists of a butterfly valve operated by the same mechanism as the controller nozzle. This butterfly valve takes the place of the combined fixed nozzles and variable nozzle. When the by-pass is in use the line to the aerator is closed by a hand-operated gate valve.

The pure-water conduit is a collecting gallery running under the full length of the effluent aerator and connected to it by slots through the concrete between every second row of aerator pipe. The pump suction is taken from the lower end of this conduit. Beyond the pump suction the water is dosed with lime and then passes through a 72-in. by 42-in. concrete Venturi meter leading to the effluent aqueduct. A second parallel Venturi meter is provided for later expansion. It might be noted here that no appreciable storage of filtered water is provided for at the plant. A filtered water reservoir of 38 million gal. capacity, with promises of future extension, is located on the outskirts of the city about seven miles from the plant.

Indicating and valve-controlling equipment for each filter is placed on an individual operating table on the floor of the operating gallery over the effluent pipe gallery. Indicating equipment is assembled in a five-dial gage and includes a loss of head gage and a rate-of-flow gage for each half filter and a water-level gage for the whole filter, also a graduated tell-tale for each controller nozzle and controller valve showing the amount that the controller is opened. At each end of the five-dial gage there is a manual shut-off for closing the controllers. Handles are provided on these tables for controlling all valves on the filter connections except the wash-water valves and the drain gates. These are operated from small tables in the central gallery. Handles are also provided on the effluent gallery tables for switching from the controller nozzles to the controller valves.

Wash water is stored in a 400 000 gal. tank on a hill about 700 ft. from the filters. The flow line of the tank is about 35 ft. above the top of the wash-water gutters. A 48-in. steel pipe connects the tank with the effluent pipe gallery. At the point of entering the gallery the pipe is temporarily reduced to 36 in. and a gate valve is placed there by which the rate of washing the filters may be regulated. In the pipe gallery a 24-in. connection is made to each filter underdrain pipe and at the extreme end of the pipe another 24-in. connection leads from the wash-water pumps.

The Service-Water Room. In the service-water room are 2 wash-water pumps, each with a capacity of 4 m.g.d.; 2 service-water pumps, each with a capacity of 200 000 gal. daily; a high-pressure pump with a daily capacity of 500 000 gal., and a vacuum priming pump. The pumps all are served by a common suction pipe leading from the pure-water conduit under the effluent aerator. The main switchboard for the plant is also placed in this room. A hand-operated 5-ton crane with a runway extending the length of the room is provided.

The wash-water and service-water pumps are controlled by float switches, a separate switch controlling each pump. The switches are set so that under normal draft only one pump will be in operation. The second pump of each set will cut in only under excessive draft or from low water due to the first pump failing to function. A double throw switch is provided for occasionally alternating the pumps, to equalize wear and to permit switching over in emergency. The service pumps supply a 2 000 gal. tank in the top of the headhouse tower. This provides water for the hydraulic valves, the filter control apparatus, the service needs of the buildings, the gate house on the main dam, and a few city-owned houses in the vicinity. The high-pressure pump serves hydrants placed around the grounds for cleaning and protection and a sand-handling system. If desired, it can be connected into the service line leading to the dam.

The Limehouse. The limehouse contains two floors and a basement. The top floor serves as a storage floor for lime. Projecting down through this floor are two conical hoppers, each with a capacity of a few hundred pounds of lime. These hoppers are provided with sliding metal shutters in the bottom which control the discharge of lime into the hopper of a dry-feed machine placed on the lower floor. This machine consists of a hopper with an agitating device and a feed screw in the bottom. The machine is driven by a variable speed motor. In addition to the variable speed motor there are provided seventeen gears for varying the speed of the feed screw. Attached to the motor is a magneto which actuates indicating and recording instruments mounted on a panel near the effluent meter registers. These instruments are calibrated to read in millions of gallons. In operation the motor is run at such a speed that the indicating instrument has the same reading as the Venturi register. The dose of lime per million gal. is controlled by changing the gear ratio. Thus the dose per million gal. is controlled by one variable speed, the other variable speed being varied according to the rate of flow. Lime will be used to keep the carbonic acid within bounds, and it is expected that very little will be required and its use may be intermittent.

The lime-feed machine discharges into a conical hopper connected to an 8-in. pipe in the basement leading to the pure-water conduit. A 2-in. pipe feeds water into the hopper to help move the lime. It might be noted that the lime is delivered downstream from the pump suction so that there is no lime in the wash water.

A Wallace and Tiernan chlorinator is installed on the operating floor of the limehouse. Chlorine will be conducted in a pipe to the effluent aerator where it will dose the water as it passes into the pure-water conduit. The use of chlorine will probably be intermittent and may be rare.

The Head House. The head house is a six-story brick and concrete tower 86 ft. high from the first floor level to the roof line. The first two stories are used for offices, machine shop, laboratories, and record rooms. The third is allotted as extra storage for alum. The fourth floor is laid out for making the alum solution and controlling the influent aerator. The fifth floor is comprised mainly of alum storage bins, sufficient area being floored over to install machinery for a bucket elevator. Above the alum bins there is another storage floor and above this the building is carried high enough to place the service tank at the elevation necessary to give the pressure required for operating the hydraulic valves.

The fourth, or alum-solution floor, is placed 6 ft. above the normal flow line of the Scituate Reservoir, so that it is always possible to deliver the alum solution to the water in the influent aqueduct without pumping it in or throttling the gates at the far end of the aqueduct to reduce the head. This permits using full reservoir head for aeration, if desired, and eliminates the wear and tear that would result to a pump handling the alum solution. The water for the alum solution is taken from the aqueduct just upstream from the point of dosing with alum solution. It is delivered to the alum solution floor by a pair of pumps placed in the basement of the head house. The solution is made in concrete hoppers built into the floor. These hoppers are 2 ft. square at the top tapering to 4 in. at the bottom and are 4 ft. deep. The solution water is brought to the hopper in a 4-in. pipe which discharges near the bottom of the hopper. The alum is fed to the hopper from a dry-feed machine similar to the lime-feed machines. As fast as the alum is dissolved the solution rises to the top and flows off in a trough leading to the intake of two 8-in. pipes leading back to the aqueduct. Three dry-feed machines with indicating apparatus similar to the lime equipment are provided. A rate of flow and water level gage connected to the influent meters is placed on this floor to assist the operator in adjusting the speed of the alum feed motors and the rate of the water entering the plant. For this latter purpose there is a switchboard on this floor for operating by Dean Control Motor Units the valves controlling the water going to the influent aerator. Above each dry-feed machine there is a weighing hopper hung from the alum bin and connected to an 8 000-pound scale. Alum is discharged from the bottom of the alum bins into these weighing hoppers. A record is kept showing the amount that is used from each bin. Computations from this record and the rate of flow charts furnish a check on the dosing computations and the faithfulness of the operator.

The Waste Wash-Water Settling Basins. An auxiliary set of basins near the Pawtuxet River is provided for holding back the waste wash water until there has been ample time for all waste material to settle before the

water is discharged into the river. It is highly important that the water should be satisfactorily clean because a series of mills extending along the river for some miles use this water for manufacturing purposes and might well consider dirty water a basis for claims for damages.

The firm of Hazen and Whipple were designers of the plant and acted as consulting engineers during construction.

PROVIDENCE, R. I., WATER SUPPLY — SOME COLOR OBSERVATIONS OF WATERS TRIBUTARY TO THE SCITUATE RESERVOIR.

BY FREDERICK OTIS CLAPP.*

[*Read September 17, 1926.*]

The drainage area contributing to the new Scituate Reservoir comprises 92.8 sq. miles of upland country, largely wooded, and wholly within the State of Rhode Island. Of this total 92.8 sq. miles, 22.3 sq. miles, or about one-quarter of the whole area, discharges its waters into the regulating reservoir at North Scituate.

The Danielson Pike, passing through the village of North Scituate, at the northerly end of Scituate Reservoir, divides this reservoir into two parts. The relatively small part north of the Danielson Pike is known as the regulating reservoir, its waters being held back by the regulating dam, a horseshoe-shaped concrete structure whose crest is 1.5 ft. above the spillway of the main dam at Kent.

The erection of this dam flooded the old North Scituate Swamp which was an objectionable natural feature lying below the flow line of the reservoir. Built by the Water Supply Board as an integral part of the main project, but completed some six or seven years in advance thereof, this reservoir has, during the period required for construction of the main dam, afforded a reserve supply which has been a very valuable assurance against a possible shortage of water due to prolonged drought.

Preparatory to flooding the area now occupied by this reservoir, the trees and brush were cut off close to the ground and the remaining area was burned over, but there was no grubbing done and no soil was removed from the surface. The reservoir may therefore be classed as an "unstripped reservoir," and we should naturally expect to find the water held in storage high in color during the first few years after filling.

The area of the regulating reservoir when full is 242 acres and its storage capacity is 428 million gallons.

It is with the color of the water in this reservoir and in the entering streams, as observed during a period of three or four years after the reservoir was first filled, that this paper has to do. This color, like that of most New England waters, comes largely from vegetable matter and jumps up noticeably in the entering streams immediately after each heavy rain. This being the case, the fact that the color observations were taken weekly, without reference to the rainfall, constitutes an insurmountable obstacle in the way of making any accurate determination of the average color of

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the water entering the reservoir between observations. However, with a practically continuous record of nearly three years at hand, we may find the general trend of the color of the water as it leaves the reservoir, as compared with the colors of the entering streams (weighted as best we may), to be of interest.

Four brooks enter the regulating reservoir, bringing the run-off from an area of 19.2 sq. miles, or about 85 per cent. of the total drainage area of this reservoir. Of this 19.2 sq. miles drained by the four brooks, Rush Brook drains 3.6 sq. miles, or about 20 per cent.; Hunting House Brook 7.0 sq. miles, or about 35 per cent.; Peep Toad Brook 4.7 sq. miles, or

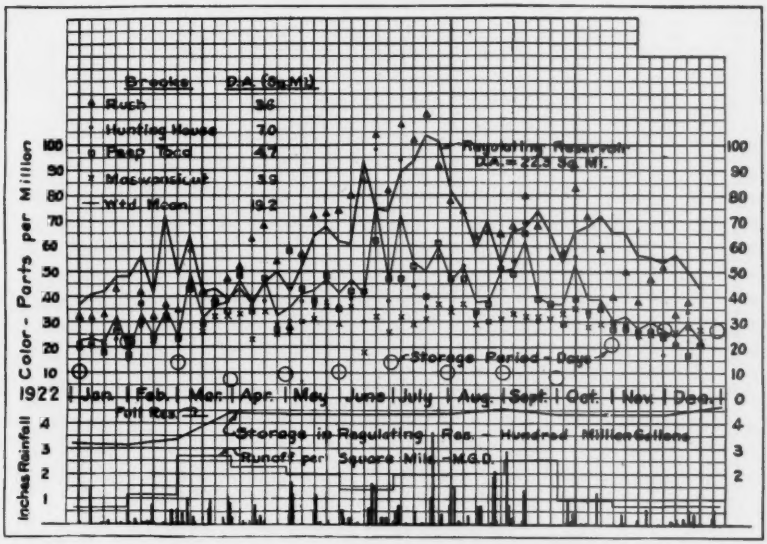

FIG. 1 — COLOR OBSERVATIONS — YEAR 1922.

about 25 per cent.; and Moswansicut Brook 3.9 sq. miles, or about 20 per cent.

The characteristics of these brooks are quite different. Of the two brooks having the smallest drainage areas, Rush Brook has much more color than any other, while Moswansicut Brook has the least, or less than one-half as much as Rush Brook. This is explained by the fact that while the flow from Rush Brook is short and sharp, Moswansicut Brook flows out of Moswansicut Pond, a natural body of water just above the regulating reservoir, which collects and holds in storage the run-off from nearly the whole of the drainage area of this brook.

Moswansicut Pond has a water area somewhat greater than that of the regulating reservoir and a storage capacity more than four times as

great, and while the regulating reservoir stores less than 20 million gal. per sq. mile of its drainage area, Moswansicut Pond stores 460 million gal. per sq. mile of its drainage area, comparing favorably with Scituate Reservoir which stores 400 million gal. per sq. mile of drainage area.

The other two brooks occupy a middle ground: Hunting House Brook, with the largest drainage area of all, having no storage upon it, while Peep Toad Brook has a small reservoir receiving the run-off from about one-half its total drainage area.

As a rough approximation to the color of the water entering the regulating reservoir, a weighted mean of the colors of the entering brooks has been

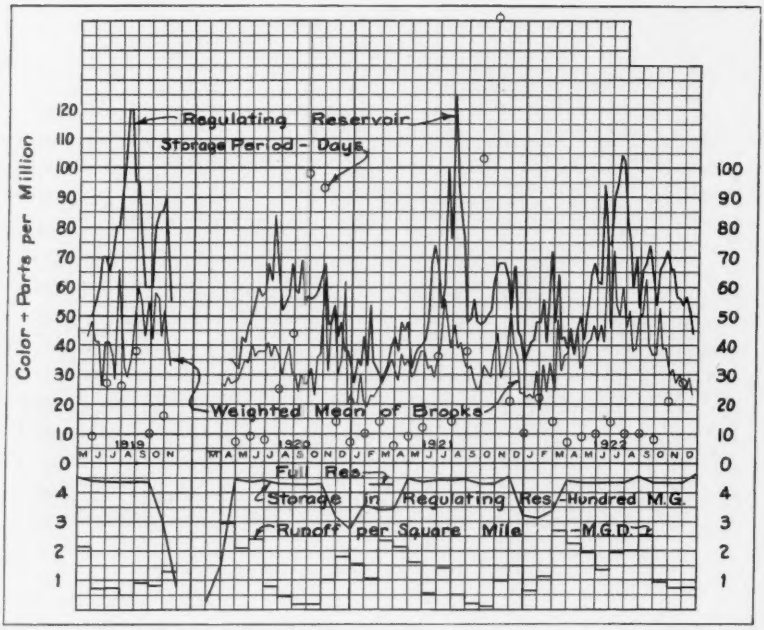

FIG. 2. — COLOR OBSERVATIONS — YEARS 1919–1922.

computed, using weights in proportion to the drainage areas above the sampling points on the several brooks.

Figure 1 shows the color observations for a single year, 1922. It shows in detail not only the weekly color observations in the regulating reservoir and in the entering brooks, but also the storage held in the regulating reservoir at the end of each month and the monthly mean run-off per sq. mile of drainage area on the Scituate watershed, which is computed from the record sheets taken from a Gurley graphic water stage register located at the Fiskeville weir some three miles below the Main Dam of Scituate Reservoir.

There is also shown, by the circles plotted at the end of each month, the approximate storage period in days, computed from the mean monthly run-off, and the quantity of water held in storage; and at the bottom is shown the mean daily rainfall on the Scituate watershed, expressed in inches.

The color is expressed in parts per million of platinum and was obtained by the standard platinum-cobalt method. The year 1922 was chosen as an example because, during that year, the regulating reservoir was never less than three-quarters full and except during the first three months was always full. Moreover, as there were no extremely low monthly run-offs, the periods of storage were more nearly normal than in the other years where full data are available.

The effect of rainfall in increasing the color of the brooks may be traced on this diagram.

Figure 2 covers the whole period during which color observations were kept up on the individual brooks, this series having been discontinued in December, 1922; and while there is a somewhat broken record of the color of the water in the regulating reservoir and in Moswansicut Pond during the next two years, Moswansicut Pond alone furnishes no adequate basis for even a rough estimation of the color entering the regulating reservoir.

Bearing in mind that the brooks have the highest colors after heavy rainfalls and that it is at these times that most of the water enters the reservoir, it would seem, inasmuch as the color observations are taken at regular intervals regardless of the occurrence of rainfall, that the weighted mean of the brook colors may be too low to accurately represent the color of the water entering the reservoir. However this may be, the diagram shows clearly that the color of the water leaving the regulating reservoir is much higher than the mean brook color as computed.

TABLE 1.

AVERAGE YEARLY COLOR OF WATER IN THE REGULATING RESERVOIR AND IN THE ENTERING BROOKS.

Year.	Rush Brook.	Hunting House Brook.	Peep Toad Brook.	Moswansicut Brook.	Weighted mean* of brooks.	Regulating Reservoir.
1919. (6 months.)	75	41	38	29	44	72
1920. (9 months.)	63	31	29	24	35	53
1921. (12 months.)	57	29	28	24	33	53
1922. (12 months.)	59	37	37	29	39	61
1923. (12 months.)	†	†	†	25	..	42
1924. (11 months.)	†	†	†	29	..	35

*Weighted in proportion to drainage area above sampling points.
†Discontinued December 20, 1922.

From the foregoing tabulation (Table 1) of yearly averages it may be seen that the average yearly color of the water in the regulating reservoir is always at least 65 per cent. greater than that of any brook except Rush Brook, and is nearly equal to the average yearly color of that brook, which represents less than 20 per cent. of the drainage area contributing to the reservoir, and that it is always at least 50 per cent. greater than the weighted mean for all the brooks.

As the regulating reservoir is shallow, the average depth being about 5.5 ft., there may be some reduction in color, due to bleaching, when the periods of storage are not too short.

That there is, however, a marked net increase in color in the water impounded in this reservoir is apparent, and that it is due to the character of the reservoir itself, an "unstripped reservoir," seems to be the logical conclusion; and this conclusion is borne out by the consistent downward trend of the average yearly color of the reservoir water, indicating that the color-producing effect of the reservoir bottom is on the decrease.

In concluding this paper, it may be remarked that the color of the water in the main body of Scituate Reservoir, which is likewise an "unstripped reservoir," should, when sufficient data have been obtained, prove a most interesting study.

PROVIDENCE, R. I., WATER SUPPLY — SCITUATE TUNNEL.

BY RICHARD R. BRADBURY.*

[*Read September 17, 1926.*]

Water from the new Scituate Reservoir is carried to Providence through the Scituate Aqueduct, the westerly portion of which consists of a tunnel about three and one-third miles long. This tunnel is in hard rock for its entire length and is of horseshoe section, 7 ft. high and $7\frac{1}{2}$ ft. wide, except for short portions adjacent to the portals, which are circular, $7\frac{1}{2}$ ft. in diameter. The entire tunnel is lined with concrete.

DESIGN.

As first laid out, the tunnel was straight between portals, but core borings on the center line developed at one place a depression in the rock surface deeper than the grade line of the tunnel. In order to avoid soft ground at this place the tunnel alignment was moved to a point about half a mile north of the straight line, the location of the portals remaining the same. This put an angle of 13° 37′ in the line at a point about a third of the way in from the west or upstream portal.

A construction shaft, located near a road crossing the tunnel line, was about midway between this angle and the east portal.

The circular sections at the ends of the tunnel were designed to seal it to the rock. In operation the tunnel will be under a head of about 20 ft. and these sections were carried in until firm rock with a minimum depth of 40 ft. over the tunnel roof was reached. The invert is carried to solid rock, the concrete lining reinforced, and the whole section grouted under light pressures to insure water-tightness. These circular sections are 258 ft. and 572 ft. long at the west and east portals, respectively.

The grades in the tunnel are very slight. The difference in elevation between the two portals, a distance of 17 642 ft., is 1.52 ft. In order to facilitate construction this grade is all in the portion 5 000 feet west from the shaft, which made it possible to drive from both portals and in both directions from the shaft without working downhill.

The shaft was located directly on the tunnel center line, 14 ft. sq. in the clear. The total depth to the tunnel invert was 140 ft., of which the first 21 ft. was in earth. This was a construction shaft and was closed with concrete and backfilled after the tunnel was completed.

The tunnel was excavated to an ordered line within which no rock was permitted to project. The shape of this line was given on the contract drawings, but its distance from the face of the masonry lining was deter-

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COMPARISON OF ACTUAL AND THEORETICAL TUNNEL EXTENSION.
CONTRACT NO. 21, DECEMBER 12, 1923.

WEST PORTAL.						WEST OF SHAFT.						EAST OF SHAFT.				
Sta.	Lin. ft. excavated.	Excavation — cu. yds.				Sta.	Lin. ft. excavated.	Excavation — cu. yds.				Sta.	Lin. ft. excavated.	Excavation — cu. yds.		
		Actual.	Theoretical.	Margin				Actual.	Theoretical.	Margin				Actual.	Theoretical.	Margin
4+40	....	0	0	0	CIRCULAR	108+30	....	0	0	0		108+60	....	0	0	0
5+40	100	271	324	53		106+50	180	518	535	17		110+10	150	485	445	−40
6+30	190	542	616	74		106+00	230	666	683	17		111+30	270	836	802	−34
7+50	310	869	1 004	135		104+80	350	1 011	1 040	29		112+10	350	1 077	1 040	−37
8+90	450	1 251	1 458	207		103+60	470	1 364	1 396	32		113+60	500	1 530	1 485	−45
10+70	630	1 758	1 992	234		101+90	640	1 916	1 901	−15		114+50	590	1 805	1 752	−53
11+40	700	1 906	2 210	304		100+50	780	2 321	2 317	−4		116+00	740	2 242	2 197	−45
12+05	765	2 152	2 481	329		97+60	1 070	3 159	3 178	19		....	....	....	....	....
14+10	970	2 718	3 095	377		96+90	1 140	3 368	3 386	18		....	....	....	....	....
16+10	1 170	3 261	3 689	428		96+00	1 230	3 639	3 653	14		120+50	1 190	3 521	3 534	13
17+80	340	3 803	4 194	391		95+50	1 280	3 784	3 802	18		....	....	....	....	....
....	....	....	....	..		94+30	1 400	4 137	4 158	21		....	....	....	....	....
19+20	1 480	4 269	4 622	353		93+10	1 520	4 479	4 514	35		123+80	1 520	4 480	4 514	34
....	....	....	....	..		92+40	1 590	4 677	4 722	45		125+60	1 700	4 961	5 049	88
22+20	1 780	5 139	5 530	391		90+20	1 810	5 304	5 376	72		....	....	....	....	....
						88+60	1 970	5 801	5 851	50		127+50	1 890	5 506	5 613	107
						....	....	....	....	....		129+60	2 100	6 129	6 237	108
						86+60	2 170	6 380	6 445	65		130+90	2 230	6 487	6 623	136
						84+30	2 400	7 057	7 128	71		132+20	2 360	6 869	7 009	140
						83+40	2 490	7 303	7 395	92		133+50	2 490	7 233	7 395	162
						81+60	2 670	7 818	7 930	112		134+40	2 580	7 487	7 663	176
						80+70	2 760	8 092	8 197	105		136+00	2 740	7 934	8 138	204
						79+30	2 900	8 470	8 613	143		137+40	2 880	8 312	8 554	242
						77+60	3 070	8 943	9 118	175		139+10	3 050	8 776	9 058	282
						76+10	3 220	9 365	9 563	198		140+80	3 220	9 240	9 563	323
						75+20	3 310	9 613	9 831	218		141+90	3 330	9 524	9 890	366
						72+00	3 630	10 476	10 781	305		146+70	3 810	10 819	11 316	497
						68+00	4 030	11 574	11 969	395		148+70	4 010	11 357	11 910	553
						....	....	....	....	....		151+30	4 270	12 062	12 682	620
						62+10	4 620	13 188	13 721	533		152+30	4 370	12 336	12 979	643
						57+20	5 110	14 566	15 177	611		158+30	4 970	14 120	14 761	641

mined in the field as the work progressed, and depended upon the character and soundness of the rock. This distance was the minimum thickness of the lining. Payment for excavation was to a line 12 in. outside of the ordered line regardless of the actual excavation. It was to the contractor's advantage, therefore, to excavate as near to the ordered line as possible without running his trimming up too high. As a matter of fact, the trimming in this tunnel was quite small although the actual excavation underran the pay excavation considerably. This was due partly to the nature of the rock, which broke well between holes, but more to the watchfulness and skill of the contractor's superintendent.

The table on page 536 gives a comparison of the actual and theoretical excavation for a part of the tunnel, including the circular section at the west portal.

Throughout the horseshoe section and the west circular section the rock encountered was a hard gneissoid granite, except for two short stretches near the west circular section where the rock was partially disintegrated. In one of these stretches timber bents were necessary to support the rock, though lagging was not used. Narrow dikes of trap were encountered occasionally. One of these, near the shaft, was 22 ft. wide, all the others only a few feet. A few seams, from 1 to 6 ft. wide and filled with fine white sand, were also encountered. Two of these required timbering.

The east portal was in schist. This rock became quite soft as the work on the east circular section progressed and was timbered for a distance of 220 ft., beginning 287 ft. in from the portal. The schist then became more firm. The change from schist to granite was near this point, though no sharp contact was noted.

The table on page 538 gives the types of tunnel used, with the minimum thickness of concrete lining.

Over 99 per cent. of the horseshoe section was untimbered and in 93 per cent. the smallest section was used. This reduced the quantities of excavation and concrete and lowered the cost quite materially.

The concrete lining of the horseshoe section is unreinforced. The side walls and arch are separate from the invert, the side walls extending about 12 in. below it. The invert is 5 in. thick, laid on hard-packed tunnel débris. Weepers of 2-in. pipe extending through it were placed at intervals of 20 ft. along the center line, to relieve upward pressure from the ground water at times when the tunnel is unwatered. Streams encountered in excavation were led through the lining into the tunnel. These streams were few and small.

The lining of the circular sections extends to the solid rock all around. No dry packing was used in the west circular section, but in the east the roof was dry-packed. Grout and vent pipes were inserted in the roof. The grout pipes extended to the top of the concrete only, but the vent pipes were placed with their tops as high as possible. A vent pipe was placed in every pocket in the roof. Streams were brought through the lining in

Station.	Length, feet.	Minimum thickness of lining, in.	Type.	
4+38				West Portal
4+38–6+96	258	6	Circular	
6+96–7+02	6	..	Transition	
7+02–9+01	199	6	Horseshoe	
9+01–11+46	245	3	Horseshoe	
11+46–12+09	63	12	Horseshoe	Timbered
12+09–17+51	542	3	Horseshoe	
17+51–18+50	99	12	Horseshoe	
18+50–44+22	2 572	3	Horseshoe	
44+22–44+77	55	12	Horseshoe	
44+77–48+73	396	3	Horseshoe	
48+73–55+54	681	9	Horseshoe	
55+54–173+94	11 840	3	Horseshoe	
173+94–175+02	108	12	Horseshoe	
175+02–175+08	6	..	Transition	
175+08–175+73	65	12	Circular	
175+73–177+93	220	12	Circular	Timbered
177+93–180+80	287	6	Circular	
180+80				East Portal
	17 642			

weepers in the same manner as in the horseshoe section. All grout and vent pipes, and nearly all weepers, were 2-in. steel pipe. A few weepers were $1\frac{1}{2}$ in. and 1 in.

The concrete of the circular section was reinforced with hoops of 1-in. sq. steel bars. These were at first spaced on 12-in. centers, but it was found extremely difficult to place the concrete of the key through such close spacing. It was therefore changed to 9 in., 9 in. and 18 in., which gave a hole every 3 ft. through which the concrete could be passed.

Construction.

The tunnel was built under contract by the Keystone State Construction Company of Philadelphia, Penn. Work was started at the site of the shaft on September 20, 1922; the contract was finished on September 29, 1925.

It was at first intended to do all of the work, except that in open cut, from the shaft in order to obtain economies in plant, camp construction, and overhead charges. The shaft excavation was completed on December 9, 1922, and the tunnel headings turned on the same day. The shaft was sunk by hand work, the earth portion close-sheeted with 3-in. sheeting braced by sets of 12 in. x 12 in. timbers on 5-ft. centers. The rock was drilled with jack hammers in lifts of about 8 ft., forty holes to the

round, mucked by hand in a tipping bucket that was handled by a stiff leg derrick.

The permanent plant consisted of three No. 10 Ingersoll-Rand air compressors, a Sturtevant blower for tunnel ventilation, a drill-sharpener with oil forge, a No. 8 gyratory crusher, bucket elevator, and rotary screen, 2 cages with hoist, 2 Hoar tunnel shovels, 4 storage-battery locomotives, muck and concrete cars, drills, etc.

This plant was run by electric power brought over a specially constructed pole line about a mile and a quarter long from the main line of the Narragansett Electric Lighting Company. The line current was 3-phase, 60 cycle, 23 000 volts; this was stepped down to 550 volts for the air compressors and shaft hoist and to 220 volts for general use around the camp and in the tunnel.

For the tunnel excavation four Water Leyner drills set up on two vertical posts were used in each heading. A round consisted of 23 holes. It was at first hoped to make advances of twelve or more feet, but this was found impracticable owing to the hardness of the rock and the narrow size of the tunnel. Advances averaged 7.7 ft. Grasselli dynamite was used, both 60 per cent. and 40 per cent. The holes were loaded rather heavily in order to break the muck up well. This was done for ease in handling and in order to make as large a proportion of the muck as possible, of suitable size for the crusher. The dynamite used per cubic yard was something over nine pounds.

Hoar tunnel shovels, air-driven, were used for mucking. They proved very successful although requiring constant attention and numerous repairs. The muck was loaded in standard end dump mine cars, hauled to the shaft by storage-battery locomotives. A single 30-in. gage track was used, with switches about half a mile apart.

Progress at the two headings driven from the shaft was slower than had been anticipated. The contractor began falling behind schedule and on June 6, 1923, work was started at the west portal. The plant was similar to that at the shaft except that but one compressor was used instead of three. Electric power from the Narrangansett Electric Lighting Company was used. On January 7, 1924, excavation was started at the east portal also. This work was done by the use of two small portable gasoline engine-driven compressors operating two drills and was carried only a few hundred feet.

The timbering in the east circular section was composed of three-piece bents of 8-in. x 8-in. square timber set on steel pins in the side walls and spaced 4 ft. on centers, lagged with 3-in. lumber and dry-packed. Grout and vent pipes were set at the same time that the dry-packing was placed.

Concrete for the lining of the horseshoe section was mixed in a central mixing plant erected at the head of the shaft. This plant consisted of a 1 cu. yd. Ransome concrete mixer arranged to discharge directly into an

8-in. wrought-iron pipe leading to a steel hopper at the foot of the shaft. Above this mixer were two large bins, one for crushed stone and one for screenings, with chutes leading directly to the measuring hopper. Above the bins was a rotary screen which separated the product of the crusher into screenings, crushed stone, and tailings. All stone over 2½in. was rejected and returned to the crusher. A No. 8 Gyratory crusher was used, mounted at the foot of the chute from the tipple into which the muck cars dumped. This crusher discharged into the boot of a bucket elevator which conveyed the crushed aggregates to the rotary screen in the top of the mixer house. Cement was hauled about three and one half miles by motor truck, from Oaklawn, the nearest railroad station, and was stored in a cement house adjacent to the mixer house. From this cement house it was transported to the charging room of the mixer by belt conveyor.

On October 31, 1924, the headings east from the shaft and from the east portal met, and six days later the first concrete for the lining was poured. This lining was cast in three sections: first, footings for the two side walls to about a foot above the invert; next, the remainder of the side walls and the arch, all in one piece; and last, the invert.

The forms for the side-wall footings were built up of wood and faced with sheet steel. They were 16 ft. long and about 2 ft. wide, light and easily handled. They were set carefully to line and approximately to grade and braced, top and bottom, to the track and the side of the tunnel. Concrete was brought from the shaft in Koppel side dump concrete cars and dumped directly from the cars into the forms.

A steel form, 150 ft. long, made by the Blaw-Knox Company, was used for casting the side walls and arch. In front of this form was a steel carriage for a concrete gun and two hoppers, and in front of this again an inclined runway 50 ft. long. The whole outfit measured about 250 ft. It was mounted on wheels running on the regular tunnel track and was pulled ahead by an electric hoist operating a tackle which was made fast to the track ahead of the incline. The form was set to grade by two rows of jacks, and to line by turnbuckles and wooden braces. The skirt of the form was braced tight against the faces of the concrete wall footings.

The concrete was placed in this form by means of a concrete gun. This machine consists of a cylinder about twelve inches in inside diameter in which moves a tightly fitting piston. The rear end of the cylinder is open at the top in the form of a hopper. The piston is drawn back to just clear this hopper through which a charge of concrete is introduced, and is then moved forward until the hopper opening is closed. Compressed air is then introduced into the cylinder in such a way that the charge of concrete is forced from the gun into and through a line of 6-in. wrought-iron pipe leading to the roof of the tunnel and along it to the far end of the form. The form is filled, beginning at the far end and working back toward the gun. The 6-in. pipe is made in 5-ft. lengths fastened together by special couplings and is shortened, one or two lengths at a time, as the work progresses.

The concrete invert was cast last. For this work steel screeds, bent to shape, were set at grade from wall to wall; the track was raised in sections about 100 ft. long and blocked up about two feet above grade, the excavation of the bottom made and concrete brought in in cars and dumped along the walls. The track was then removed, the concrete pulled down to the center and screeded with a 6-in. pipe.

The lining of the circular sections at the two portals was placed by hand, the method being practically the same in each case. The invert was cast first, screeded in 16-ft. lengths. Wooden ribs were then erected and the lagging, which was of 3-in. x 3-in. x 16-ft. hard pine, was placed a few pieces at a time as the concrete was shovelled into the form. The last five feet across the top of the arch was mixed very dry, placed in 4-ft. lengths and rammed back hard against the roof of the tunnel. Grout pipes were placed in this roof about every 15 ft.

At the east portal the concrete was mixed in a half-yard stream-driven portable concrete mixer and transported to the forms in a small car drawn on a track by a horse. At the west portal a half-yard gasoline-driven mixer was used for mixing and concrete buggies for transportation.

The circular sections were grouted, using a Caniff grout machine with air pressures up to about 25 lbs. Grouting was started at the portals and carried straight ahead to the end of the circular section, taking each pipe as it came. The weep holes as a rule did not take a large amount of grout, the maximum in any one hole being 2.4 cu. yd.; nor did the grout travel far to appear in some other hole. When grouting in the roof, a considerable length of tunnel could be grouted from a single hole. The maximum amount of grout forced into a single hole in the roof was 52 cu. yd. and the maximum distance through which grout was forced was about 100 ft.

Grout was composed of neat Portland cement and water and was mixed in varying proportions from 1 to 4 to 1 to 1. Unless it was known that a hole was quite open, the start was made with the thinnest grout, working up gradually to the thicker as the hole showed ability to take it.

Cost.

The tabulation on page 542 gives the actual cost of the tunnel to the city, as paid to the contractor. This is based on the various tunnel items of the contract, the quantities being taken from the final estimate.

In considering these costs it should be borne in mind that there were two factors that undoubtedly reduced them considerably. One of these was the unexpected soundness of the rock through which the greater part of the tunnel was driven. When 93 per cent. of the main section can be made of the minimum size, large economies are obtained in excavation, concrete, and cement, which could not be expected under usual conditions. The second factor was the low unit prices bid by the contractor. Although

his work was carried on with a high degree of efficiency, it was not possible to carry the contract through and make a fair profit at these figures, and it should not be assumed that they are likely to be repeated.

The only variable items on the contract besides excavation, concrete, and cement, were the timbering items, dry-packing, and the grouting items. These were all extremely small in quantity and this also decreased the actual cost of the tunnel.

Description.	Unit.	Quantity.	Unit price.	Total cost.	Cost per ft. of tunnel.
Sinking shaft in earth	lin. ft.	21.06	$250.00	$5 265.00	$0.30
Sinking shaft in rock	lin. ft.	118.80	300.00	35 640.00	2.02
Excavation in tunnel	cu. yd.	53 129.93	12.00	637 559.16	36.15
Enlargement of tunnel	cu. yd.	524.40	16.00	8 390.40	.48
Permanent timbering in tunnel	M bm	17.976	110.00	1 977.36	.11
Temporary timbering in tunnel	M bm	5.613	130.00	729.69	.04
Shaft and tunnel drainage	lin. ft.	17 774.72	1.00	17 774.72	1.01
Forms for masonry lining	lin. ft.	17 638.78	2.00	35 277.56	2.00
Concrete, horseshoe section	cu. yd.	20 342.15	7.00	142 395.05	8.07
Concrete, un-reinforced circular section	cu. yd.	19.98	10.00	199.80	.01
Reinforced concrete	cu. yd.	1 433.75	11.00	15 771.25	.89
Dry-packing	cu. yd.	265.42	2.00	530.84	.03
Drilling holes in rock or masonry	lin. ft.	404.60	2.00	809.20	.05
Steel pipe for grouting, etc.	lin. ft.	1 186.00	.40	474.40	.03
Making connections for grouting	each	120.33	1.50	180.49	.01
Grout	cu. yd.	397.28	15.00	5 959.20	.34
Portland cement	bbl.	30 005.50	3.00	90 016.50	5.10
Steel for reinforcing concrete	lb.	95.411	0.05	4 770.55	.27
Liquid chlorine	lb.	1 965.00	0.20	393.00	.02
Chlorine dosing machines	each	2.00	2 500.00	5 000.00	.28
Locker houses	each	2.00	4 500.00	9 000.00	.51
Cleaning up		.....	1 000.00	1 000.00	.06
Extra work		486.12	.....	486.12	.03
Total cost				$1 019 600.29	$57.81
Shaft excavation				40 905.00	2.32
Total cost exclusive of shaft excavation				$978 695.29	$55.49

PROGRESS.

Progress on the various portions of the work was as follows:

	Length, ft.	Time, days.	Rate, ft. per day.
Shaft:			
Excavation	140	70	2.0
Horseshoe section:			
Excavation east from shaft	6 550	667	9.8
Excavation west from shaft	6 664	753	9.3
Excavation from west portal	3 478	502	6.9
Concrete east of shaft	6 658	111	60.0
Concrete west of shaft	10 142	98	103.5
Invert east of shaft	6 658	70	95.1
Invert west of shaft	10 142	79	128.4
West circular section:			
Excavation	264	41	6.4
Concrete	264	35	7.5
Grouting	258	6	43.0
East circular section:			
Excavation	578	251	2.3
Concrete	578	176	3.3
Grouting	572	49	11.7

FIELD WORK.

Lines and grades for the tunnel excavation and the lining were given by the city force. An approximate center line had been run out and monumented several years before the letting of the contract. The first field work was to pick up and straighten this line. After an approximate line had been reëstablished it was cleared about 30 ft. wide, additional monuments were set near the shaft, and permanent backsights were erected as far from the shaft as could be seen. This line was permanently established before the shaft sinking had reached tunnel grade, and was never changed after tunnel excavation had begun.

The surface center line was transferred to the tunnel through the shaft in the usual method, by plumb line. For plumbing, No. 8 piano wire was used, wound on specially designed reels. Each wire was supported at the top of the shaft by a grooved wheel which could be moved crosswise of the tunnel center line by a slow motion and held when set by a clamp nut. The device permitted very precise setting of the wires. Plumb bobs were of 4-in. angle irons riveted back to back; their weight was about 20 lbs. Ordinary 14-quart galvanized iron pails were used for the water in which these plumb bobs hung.

Line in the tunnel was carried on brass scales fastened to wooden plugs which were driven into holes drilled in the tunnel roof. These scales were set about 200 ft. apart, the most advanced scale being at least 500 ft. from the heading, to avoid injury when blasting. The scales were divided for a length of about six inches, in tenths and hundredths of feet; a rider with a hole for a plumb bob string carried the reading to thousandths by means of a vernier.

After the tunnel headings had advanced far enough to set the second scale each way from the shaft, line-dropping was begun. This work was done on alternate Sundays, as the contractor was not working at those times. Line was dropped and transferred to the six scales nearest the shaft seven times. This gave a base line in the tunnel about 1 000 ft. long, which was prolonged by ordinary double centering methods until the headings met. Line was carried in at the two portals by ordinary careful surveying methods. The shaft center line was produced eastward 6 564 ft. and met a line carried in from the east portal 672 ft., with an error of 0.18 ft. It was produced westward 6 664 ft., carried around a two-degree curve about 700 ft. long and met a line carried in from the west portal 3 742 ft., with an error of 0.40 ft.

For giving line and grade to the contractor for marking his headings, a temporary line was carried ahead of the scales on nails driven into wooden plugs in the tunnel roof. These plugs were at first set about 40 ft. apart, but this distance was gradually lengthened out until on the last plugs it averaged over 100 ft. The line carried on these roof plugs was used for all construction work whether it varied from the true line carried on the scales or not. It was frequently checked with the true line, however, and not allowed to vary materially from it.

Line and grade for the concrete wall footings were given by setting wooden crosspieces horizontally across the tunnel, high enough to permit a train to pass under, nailing vertical wooden strips to these at the right distance out from the center, and setting a grade nail in each vertical strip. The crosspieces were set about 40 ft. apart.

Line for the steel arch and side wall form was furnished by the previously cast wall footings, grade was given by painting points about 25 ft. apart on projecting rock in the tunnel roof, numbering these points and providing inspector and foreman with a tabulated list of distances to measure down from them.

Trimming was marked on the roof and sides of the tunnel by means of a templet of half the tunnel made of shingle lath. This was plumbed by a small level bubble fastened to one of the crosspieces and centered sometimes by a leg reaching to the shoulder of the side-wall footings and sometimes by setting a center line string at a predetermined height.

Record sections of the actual excavation were taken at 10-ft. intervals. These sections were taken by means of a sunflower machine.

Personnel.

The Scituate Tunnel is Contract 21 of the Water Supply Board of the city of Providence. Both design and construction were under the supervision of the Chief Engineer, Frank E. Winsor; William W. Peabody is Deputy Chief Engineer, and Francis B. Marsh, Designing Engineer. The writer was in charge of the field work and construction as Resident En-

gineer, assisted by Wilfred D. Chapman and Philip S. Brown, Assistant Engineers.

The Contractor, The Keystone State Construction Company, was represented by Paul G. Brown, General Manager, with Philip Pagliaro as Resident Superintendent.

PROVIDENCE, R. I., WATER SUPPLY — SCITUATE AQUEDUCT IN OPEN CUT.

BY THOMAS T. ALLARD.*

[*Read September 17, 1926.*]

Continuing in an easterly direction from the easterly end of the tunnel, Contracts 34 and 35 complete the carrier structure, ending at Reservoir Avenue, Cranston, a distance of about 2.9 miles from the tunnel. This portion of the line is commonly spoken of as the "Cut and Cover Section." Two types of construction are met with in this end of the work. The first, under Contract 34, is a reinforced concrete aqueduct, with a circular waterway 7 ft. 6 in. in diameter. This extends from the tunnel easterly to the siphon chamber, a distance slightly less than one mile.

The siphon chamber is a reinforced concrete structure, extending to Elev. 252.5. It is really a junction chamber uniting the concrete aqueduct of Contract 34 with the steel pipe line of Contract 35, having also a connection for another pipe line under Contract 41. The chamber is housed with a tile-covered brick building containing a movable hand-operated hoist for placing and removing steel stop-gates. These steel stops are made in 6-ft. lengths, and work in channels, there being a set for each pipe line. The brick superstructure was erected under Contract 40.

The conduit from the siphon chamber, under Contract 35, is of riveted steel pipe, which extends easterly for about 1.9 miles, where it connects with two cast-iron city mains, each of 30 in. diameter, which now take water from the Sockanosset Reservoir.

CONTRACT 34.

This contract was awarded to the lowest bidder, Cenedella and Company, December 3, 1924, and work began on December 11. It comprises the concrete aqueduct from the tunnel to the siphon chamber; the concrete portion of the siphon chamber; concrete culverts; several rights of ways, graded, for adjacent property owners; graded access roads, one for each end of the aqueduct; and the fencing of a portion of the city property lines on Contracts 34 and 35; the fencing was of galvanized iron wire strung on reinforced concrete posts spaced about 16 ft.

The aqueduct passes through wooded and pasture lands, deviating with a few short curves of radii of 200 ft., to avoid deep cutting. There was rock cut at the west end for about 400 ft., the maximum depth of which was about 17 ft. With the exception of a few small ledge outcrops, the remainder of the way was in earth cut and fill. The material was princi-

*Resident Engineer, Providence Water Supply Board.

pally sand and gravel, with a liberal mixture of boulders. The maximum cut was about 30 ft., and the maximum fill about 15 ft.

Construction. All topsoil was first stripped from the sites of excavation or embankment and piled separately for final surface loaming. Where soft material was encountered below the required grade, it was excavated and refilled with compacted gravel. General excavation began at the easterly end, working towards the tunnel.

Steam shovels were employed, keeping about six inches above grade, the bottom six inches being removed by pick and shovel. Where the masonry was built on embankment, the fill was rolled in thin layers, watered where required, to not less than six inches above the final grade. When ready to proceed with the masonry, the fill was carefully graded to the required shape.

A 3-in. blanket of concrete was placed on the prepared earth foundation, and on this were built stepped-up concrete blocks at 5-ft. intervals, to serve as supports for the inside invert forms, and the reinforcing rings.

The concrete aqueduct is circular inside, with a diameter of 7 ft. 6 in. The concrete is 10 in. thick at the crown, becoming thicker as it curves to tangency with straight sides battered to 4 on 1. The bottom width is 12 ft. The invert thickness above the 3-in. blanket is $11\frac{1}{2}$ in.

The reinforcing rods are of $\frac{3}{4}$ in. round deformed steel, forming inner and outer hoops, 10 in. on center and staggered. The longitudinal tie rods are of $\frac{1}{2}$-in. steel.

Steel Forms, and Method of Using. Steel forms were employed throughout the aqueduct work. They were manufactured by the Blaw-Knox Company, Pittsburgh, Penn. The inside forms are made up of angle and channel stiffeners, covered with sheet steel, in 5-ft. lengths with flanged ends for bolting together into any desired length. Thirty-foot lengths were the units used on this work. The invert section is detachable, and has a narrow, rigid track for carrying the inside traveller. The sides and arch are hinged along three longitudinal lines so that they may collapse away from the concrete and on to the inside traveller, when they are to be moved to another point.

The inside traveller is a steel framework, mounted on flanged wheels which run on the invert track. A rigid truss extends lengthwise along the traveller, and to this are pin-connected steel arms, threaded and provided with ratchet jacks. These arms are also pin-connected to the inside forms, and serve to accurately and rigidly adjust the forms in place, and to collapse them on to the traveller.

The outside forms are made up into a framework conforming to the shape of the concrete section, having ribs and longitudinal members of angles and channels. With the exception of an open space left along the top for depositing the concrete, the framework was covered with sheet steel, with removable panels along the sides near the bottom, for inspection, and working the concrete under the invert. Long bolts connected the inside and outside forms, which enabled accurate spacing.

The outside traveller was a steel rectangular framework made up of angles and channels, with I beams spanning the outside forms, about 3 ft. above same, and having ratchet-operated steel arms for raising and adjusting the forms, and similar arms attached to the forms and legs of the traveller. The traveller was mounted on double-flanged wheels which ran on T rails spiked to timbers on each side, clear of the forms.

Method of Using the Forms. The reinforcing steel hoops were first wired in place, forming a rigid circular cage, resting on the steps of the concrete blocks. Thirty feet of the steel invert were next placed and bolted together; a 30-ft. inside traveller was placed on the track and the remainder of the 30-ft. section of the inner forms was assembled and adjusted by means of the arms connecting the traveller and the forms. A 30-ft. section of outside forms was then assembled in place, and the 30-ft. outside traveller erected on its track and connected to the outer forms. Open ends of the forms were bulkheaded. A flat steel ring, $\frac{3}{8}$ in. by 4 in., well coated with bituminous paint, was placed at all joints, to serve as a water stop.

With all in readiness, the forms were filled with concrete. The concrete was properly screeded and trowelled where the forms were open on top.

On the following day, a second 30-ft. section of reinforcing steel was wired in place, and a second complete 30-ft. section of inside forms was set up. The outside traveller then raised the outside forms from the previous work and brought them ahead to complete the forms for the second section, the inner forms of the first section being left undisturbed. The next day a third 30-ft. section of invert was placed, and the inside traveller was rolled back into the first section, the invert disconnected from the upper portion of the forms and the latter collapsed on to the traveller which was rolled ahead through the reinforcing cage of section three, and the collapsed forms were adjusted in place to complete the inner forms of this section. The outside forms were then raised from section two and brought ahead with the outside traveller to complete the forms of section three, which was concreted the same day.

On the fourth day, the invert of section one was brought ahead by hand, sliding it along on the track under the traveller, which could be elevated for the purpose, by means of the ratchet arms, and placed for section four.

This completed the cycle of the form manipulation, which was repeated as the work progressed. Thus working continuously, setting up and filling a 30-ft. section each day, the outside forms remain on the concrete for about 18 hours and the inside forms remain undisturbed for about 42 hours on each 30-ft. section.

It is seen that the form equipment consisted of 60 ft. of inside forms complete with 30 ft. of extra invert, 30 ft. of outside forms, a 30-ft. inside traveller and 30 ft. of outside traveller. The outside traveller, carrying the outer forms, was hauled ahead by use of cable and snatch-blocks from a nigger-head on the mixer.

The concrete plant consisted of a tower with an inclined runway to the top, with a ½-yard mixer at the foot of the runway, and a cable-operated car which delivered the concrete from the mixer to the top of the tower, and automatically dumped it into the chute. All was mounted on a track at one side of the work.

The average force was 22 men and a foreman. This gang could assemble the rods, change and set up the forms for a 30-ft. section in about 4½ hours, and mix and fill the forms in about the same time.

So regularly did this work proceed, that for many consecutive days at periods of the work, a 30-ft. section was completed each day. From June 6 until September 19, 1925, 2 850 ft. of aqueduct were constructed, making an average of 27.1 ft. per day for 105 consecutive days. This gave an average of 43.63 cu. yd. of concrete each day, each 30-ft. section containing 48.3 cu. yd.

The contractor did not own the steel forms, but paid $9 000 rental for the use of them. This shows a cost of $1.11 per cu. yd. of concrete for the steel forms. The labor for setting up the forms consisted of eight men and a foreman for four and one half hours, making the labor cost about $0.45 per cu. yd., or a total cost of $1.56 per cu. yd.

The mix was 1:2:4. The cement used was that of the Pennsylvania Portland Cement Company, Bath, Penn. Concrete work was suspended during the freezing months, and completed early in the spring of 1926.

The aqueduct has an earth cover, 2 ft. 6 in. deep on the crown, with a level width of 9 ft. and slopes of 1 on 1¾. The top 6 in. is loam which will be fertilized and seeded to grass.

Grouting Construction Joints. The construction joints opened slightly on the inside of the aqueduct during the winter, some of them to a width of $\frac{1}{16}$ of an inch; so grouting was decided upon. As soon as the temperature inside would permit, early in the spring, grouting was started with a force of four men. The joints were raked out and worked over until a small groove was obtained all around, except on the bottom section, which showed no openings. Shallow holes were drilled, in which the grout pipe was caulked with lead wool. A small Douglass hand pump was used to force the grout, and in place of caulking the joint all around to confine the grout, a wooden circular dam was devised, having a soft rubber rim or tire, which could be expanded tight against the concrete over the joint. The wooden portion of the rim was made in six segments, cut to the circle of the concrete. These segments were linked at their ends to arms radiating from the center. The outer ends of these arms were moveable, wedges being used to force them out, thus squeezing the rubber ring tight against the joint.

Two important precautions are to be taken: First, see that the crack is widened at the surface, forming a small continuous groove so that in places where the joint may be pinched together enough to block the flow of grout, it may pass through the groove and enter the crack beyond. Second, the

wedging out of the arms must be done evenly all around to preserve the true circle of the rim, or a leaky job will result. Men will continuously disregard these precautions if they are not carefully directed until trained to recognize their importance. They will invariably claim that the concrete is out of true, when in reality it is their rim which is distorted. The grout pipe was provided with a shut-off valve which was always closed before pressure was released at the pump.

A second similar dam was made and put in use after the first one proved successful. This very much more than doubled the progress, as it permitted one to remain in place long enough to allow the grout to set sufficiently to remain firmly in the joint, while the other form was being set up and its joint grouted.

The steel forms used on the aqueduct left a very satisfactory interior surface, with good uniformity throughout, as to shape, line, and grade. The aqueduct has a continuous descending grade of 0.06 per 100 ft.

The concrete was kept moist by applying water and a cover of moist earth as soon as forms were removed.

In addition to the concreting outfit, previously mentioned, the contractors' equipment consisted of three ½-yard Erie steam shovels, one ½-yard steam concrete mixer, one ½-yard gasoline mixer and one ¼-yard gasoline mixer, one air compressor, three jack hammer drills, an average of two 7-ton trucks and various pumps and small tools.

Contract 35.

From the siphon chamber to the end of this contract, the water is to be carried through riveted steel pipe. About 1.6 miles of this has a diameter of 66 in.; the remainder, about 0.3 mile, has a diameter of 48 in. The 66-in. pipe terminates at Budlong Avenue, in the city of Cranston, where it connects with a 42-in. city main, which takes water at present from the Sockanosset Reservoir. From here a 48-in. pipe continues the line to the end of the contract at Reservoir Avenue, where connection is made with two 30-in. city mains which take water at present from the Sockanosset Reservoir.

The contract was awarded to the lowest bidder, Charles A. Haggerty, of Webster, Mass., on February 6, 1925, and work was started February 25, of the same month.

The pipe was fabricated and laid for the contractor by the Pittsburgh-Des Moines Steel Company, Pittsburgh, Penn. The coating material for the pipe was furnished and applied by the Wailes Dove-Hermiston Company of New York City.

Several culverts were built under the pipe line, and galvanized iron corrugated pipe was used for drainage where cross-over roadways were graded for adjacent landowners. The line crosses under several highways, the New York, New Haven and Hartford Railroad, and the Pocasset River. Manholes and blowoffs are provided at appropriate points along

the line, and an automatic air valve, in a concrete chamber, is located at the summit of Deans Hill. This air valve is of the type made by the Multiplex Manufacturing Company, Berwick, Penn., and is known as the "Crispin Air and Vacuum Valve." It is in the form of a cluster of three air and vacuum valves, combined with one pressure air valve.

The pipe line passes mostly through farm lands, and has quite an irregular profile. The invert elevation at the siphon chamber is 222.25. It descends from here to an elevation of 68.00 at a blowoff at Angell's Pond, then rises to an elevation of 158.00 at the air valve on the crest of Deans Hill. From here it descends to its lowest level at the Pocasset River where the invert elevation is 12.00. It rises gradually from here to its end at Reservoir Avenue, the elevation at this point being 17.3. The maximum grade was 19.17 per cent. The maximum cut was about 20 ft., and the maximum fill about 15 ft.

Construction. Before beginning the general excavation, the topsoil was removed from the sites of excavations and embankments and stored by itself for final top dressing.

Excavation was done mainly by machinery, the final bed for the pipe being carefully brought to the true grade by hand work, with all stones removed, and compacted. Where rock was encountered, it was excavated so that in no case would rock be nearer than 6 in. to the pipe, a compacted earth bed being provided, not less than 6 in. deep, under the pipe in rock cut. Where the pipe was laid on embankment, the foundation embankment was built up in 6-in. layers and thoroughly rolled, water being applied when directed. The compacted embankment was brought up to 6 in. above final grade. When ready for actual pipe-laying, the pipe bed was excavated to the true grade by hand work.

After the pipe had been placed, riveted, and caulked, tested under water pressure, and the exterior coatings applied, an earth refill was compacted around the pipe as high as the bottom half. The completion of the earthwork consisted of an earth cover over the pipe 2 ft. 6 in. deep at the top, with a level width of 9 ft. and side slopes of one on one-and-three-quarters, the upper 6 in. of the top and slopes being of loam. The loamed surfaces were finally fertilized (600 lbs. to the acre) and seeded to grass with the following mixture: 25 lbs. red top, 10 lbs. red fescue, 10 lbs. Kentucky Blue, 15 lbs. oats; 60 lbs. per acre.

Drainage was provided all along the line, by side ditching, and by means of pipe and concrete culverts, and open paved gutters.

Excavation was accomplished with two steam and two gasoline-operated excavators, employing also trucks, two tractors, about 2 000 ft. of track on a portion of the work, with a gasoline locomotive, three compressors, two jack hammer drills, various gas and hand pumps and the usual hand equipment.

Steel Pipe. From the siphon chamber, about 1.6 miles of 66-in. riveted steel pipe were laid, connecting at Budlong Avenue with a 42-in. city main.

From this point to the end at Reservoir Avenue, the pipe had a diameter of 48 in. The pipe in general had a thickness of $\frac{5}{16}$ in.; $\frac{3}{4}$-in. rivets were used, rivet holes being punched $\frac{13}{16}$ in. in diameter. The holes were centered $1\frac{1}{8}$ in. from the edge of the plate, and about 2 in. on single riveted joints. Rivet holes on the inside of the pipe were counter-sunk about $\frac{3}{32}$ in. The quality of plate and rivets, also the workmanship of both shop and field work, accorded with the requirements given in the "Standard Specifications for Structural Steel for Bridges" of the American Society for Testing Materials, and with the best accepted practice for work of a similar nature.

Shop joints were tested before delivering the pipe to the job. The pipe was made up in 30-ft. lengths, except the specials for curves, angles, connections, and closing pieces. The pipe was fitted to steel castings for all required manholes, valves, or other connections. All pipe was thoroughly cleaned and given a coat of Bitumastic Solution applied cold, followed by a heavy brushed coating of Bitumastic Enamel applied hot. This treatment was given to both the inside and the outside of the pipe, after it had satisfactorily passed the pressure test. The coating material was manufactured and applied by the Wailes Dove-Hermiston Corporation of New York.

The field riveting and caulking was done with air hammers and caulking tools in sections of a few hundred feet in length, then tested with a water pressure not less than that to which it will be subjected when in service. Following the pressure test the protecting coatings were applied, and an earth cover thrown up as soon as possible to protect the coating from injury.

Pipe-laying began about the middle of June, 1925, and was completed the last of January, 1926. During the hot summer months the air inside the pipe attained a temperature as high as 136° Fahr. A coating of whitewash was applied over the black coating, on the outside, which produced a decided reduction of the temperature inside the pipe.

A wet bottom was encountered in the section from the Pocasset River to Reservoir Avenue, so the pipe trench was excavated from one to two feet below grade and refilled with gravel; in this was laid a tile drain graded to drain from Reservoir Avenue to a sump near the river where pumps were installed, keeping the trench in good workable condition. Pipe-laying started from the Reservoir Avenue end, working back toward the river. In the meantime the river was turned into a new temporary channel to the west, enabling the pipe work to continue under the original bed which was subsequently restored and the river turned back into it.

On August 27, 1925, following a pressure test, the contractor started to empty a bulkheaded section of pipe near the air vent chamber before a man, whom he had sent for the purpose, had opened the air vent at the far end of the section. As a result, seven 30-ft. sections of 66-in. pipe collapsed down from the top, spreading the sides outward. The top dished down below the sides to such an extent that at the point of worst condition

it was only 4 in. from the invert. Water was again pumped into the pipe until sufficient pressure had been applied to restore it to about its normal shape. After remaining under pressure for a few days the pipe was emptied, when it assumed an elliptical section, without sharp bends. Screw jacks were then employed inside the pipe, it was again filled with water under pressure and left for a few days, then emptied and 35 and 50 ton jacks were used at each joint, raising the top slightly above its normal height. Jacks were also used against the exterior sides of the pipe. It was once more filled under full test pressure, thoroughly caulked and painted, and found acceptable. Earth fill was then compacted around and to the top of the pipe while under pressure, along the section which had been deformed. About a month elapsed from the time of the accident until the completion of this work.

PROCEEDINGS.

November Meeting.

Hotel Bellevue, Boston.
Wednesday, November 10, 1926.

The President, Frank E. Winsor, in the chair.

President Winsor announced the death of Desmond FitzGerald, a past president and also an honorary member of this Association.

Charles W. Sherman and John C. Chase spoke on the life of Mr. FitzGerald.

A paper on "Proposed Legislation relative to Free Distribution of Trees by the Commonwealth to Municipal Water Departments," was presented by Harris A. Reynolds, Secretary, Massachusetts Forestry Association, Boston, Mass. Henry A. Symonds, Hugh McLean, Charles E. Kendall, Stephen H. Taylor, and Dwight Porter took part in the discussion.

A paper on "Public Ownership at Bridgewater, Mass., and the Improvements Made after Purchase by the Town," was read by Frank A. Barbour, Consulting Engineer, Boston, Mass. David A. Heffernan and Henry A. Symonds took part in the discussion.

(*Adjourned.*)

December Meeting.

Hotel Bellevue, Boston,
Wednesday, December 8, 1926.

The President, Frank E. Winsor, in the chair.

President Winsor. I think Mr. Sherman has a matter to present to the Association.

Charles W. Sherman. Mr. President, the legislative session is going to begin at the State House very soon, and it occurred to some of us within a few days that there was at least one matter that this Association might well make itself felt in, and that is the further protection of the purity of waters in our reservoirs.

As probably most of you know, a couple of years ago the Metropolitan District Commission obtained an act allowing it to drive gulls away from the Chestnut Hill and Spot Pond reservoirs by firing loaded cartridges, and I understand that they have had somewhat greater success in driving away the birds since then than before. At any rate, it is a step in the right direction.

Now, if it is a good thing for the Metropolitan Water Supply, it ought to be a good thing for the rest of us. We ought to have a general law,

instead of a special law, allowing the use of such force as may be necessary to drive away these polluting birds from our water-supply reservoirs. The thing came rather forcibly to my attention a short while ago when a member of our organization showed me a photograph he had recently taken of a water-supply pond in which was a large rock liberally streaked with white from the droppings of gulls. We all know what that means to the water of the reservoir.

That same subject was brought forcibly to my attention a few days ago when I was talking with our past president, Mr. Davis of Philadelphia. He told me of the similar trouble that they had with their reservoirs and standpipes. It was pigeons that caused the trouble in their case.

Now, if we can do anything to limit the amount of the nuisance caused by birds, we ought to do it, and the legislation obtained by the Metropolitan District Commission seems to be an entering wedge.

I offer the suggestion that we petition the Legislature for an act, amending the present one, to make it of general application. I have a draft of such a bill prepared, but I do not think it is necessary to read it. The idea is to permit the use of loaded cartridges, where necessary, in driving away birds which may defile the water; with a provision that there shall be a report made annually of any birds shot by such practice, to the Commissioner of Fisheries and Game.

Mr. President, I make a motion that the Legislative Committee of the Association be authorized to file such a bill in the name of the Association.

H. V. Macksey. I second the motion.

President Winsor. Gentlemen, you have heard the motion, duly seconded. Is there any discussion?

I would say that the Executive Committee endorsed this action at their meeting this morning.

(*The motion was carried.*)

I think Mr. Brehm has a matter to bring before the Association at this time.

George C. Brehm. About a month ago I was over at Dedham and talked with Mr. Gifford relative to a betterment assessment for water mains. Now, I am not trying to claim any originality on these betterment assessments, because I know it has been spoken of several times, but I feel that if the Association presented a bill to the Legislature it would get much more backing and receive much more consideration than it would from an individual; and with that in mind I asked Mr. Gifford if at the next Executive Committee meeting he would present it and see how the Association felt about it. Mr. Gifford presented it and a Committee, consisting of Mr. Sherman, Mr. Weston, Mr. King, Mr. Taylor, and myself were appointed to draft a bill. We held a meeting yesterday afternoon and made up a rough draft of a betterment bill, and I think I will read that bill.

The first section follows along the general lines of the General Laws, chapter 80, regarding betterment assessments, because it has to be that way in order to make it legal.

"Be it enacted by the Senate and House of Representatives in General Court assembled, and by the authority of the same, as follows:

Section 1. Whenever a limited and determinable area receives benefit or advantage, other than the general advantage to the community, from the extension of a water main or the construction of or addition to a plant in connection with said extension made by or in accordance with the formal vote or order of a board of officers of a city, and such order states that betterments are to be assessed for the improvement, such Board shall, within six months after the completion of the improvement, determine the value of such benefit or advantage to the land within such area and assess upon each parcel thereof a proportionate share of the cost of such improvement, and shall include in such cost all damages awarded therefor under Chapter 79; but no such assessment shall exceed the amount of such adjudged benefit or advantage; and no assessment shall be made when the main is less than six inches in diameter.

All money with interest collected by the city for such assessments shall be credited to the Water Department and shall be used only for the extension of water mains, or the redemption of water bonds."

Now, at the meeting yesterday we went a little further with that particular section, and instead of just having it for the extension of water mains or the redemption of water bonds, it was suggested that it read similar to section 1 where it says, "from the extension of a water main or the construction of or addition to a plant in connection with said extension made by or in accordance with the formal vote or order."

"Section 2. Section 2 of Chapter 80 of the General Laws, and all provisions of said chapter 80 relative to the apportionment, division, assessment, abatement and collection of assessments, and to interest, shall apply to the assessments, made under this chapter."

At the meeting yesterday afternoon those present felt that the Water Commissioners or the Water Boards should have the power to make these assessments, and that all hearings relative to betterment assessments on water mains under the General Laws should be before the Water Commissioners, and we are going to have that inserted here.

I do not know of anything else that is in the bill, or any other changes. What we would like to do, as I understand it, is this: the Executive Committee have endorsed this at their meeting today — have they not, Mr. Gifford?

SECRETARY GIFFORD. Yes.

MR. BREHM. Of course this bill is like all other bills, and the Committee cannot put it over — that is impossible. The bill is going to receive a lot of opposition. I think that the bill is due for quite a lot of opposition. And I also found out that Mr. Waddell is very much against such a bill as this. So that we are going to have an uphill fight, and personally I feel that a little coöperation from the Association will get the thing across, and I personally would like to see the thing go across.

I do not think there is anything else I can say. Perhaps Mr. Taylor or Mr. Sherman would like to add a few words.

GEORGE A. KING. This bill is to apply to towns and water districts, as well as to cities.

PRESIDENT WINSOR. I understand, Mr. Brehm, that you made that as a motion?

MR. BREHM. I meant to do that. I move that the Association endorse the legislation.

(*The motion was duly seconded by Charles W. Sherman, and carried.*)

A paper on "Military and Emergency Water Supplies" was read by Major George C. Danforth, Corps of Engineers Reserve, U. S. A.

A discussion of subjects of interest to superintendents having been announced for this meeting, a short discussion was had on the subject, "What Supervision, if any, is given to Auxiliary Connections to Public Water Supplies"; followed by a discussion on the subject, "Recent Practice and Experience in the Use of Paint on Standpipes." These discussions were participated in by David A. Heffernan, John F. Sullivan, Secretary Gifford, George C. Brehm, P. S. Nugent, A. H. McDonald, S. G. Wylie, Morrison Merrill, Arthur D. Weston, Charles W. Sherman, and Henry T. Gidley.

On motion of Arthur D. Weston, duly seconded, it was voted that a committee be appointed to investigate into the matter of the painting of standpipes and other structures, to determine the best practice to adopt, and to report as early as possible to the Association.

(*Adjourned.*)

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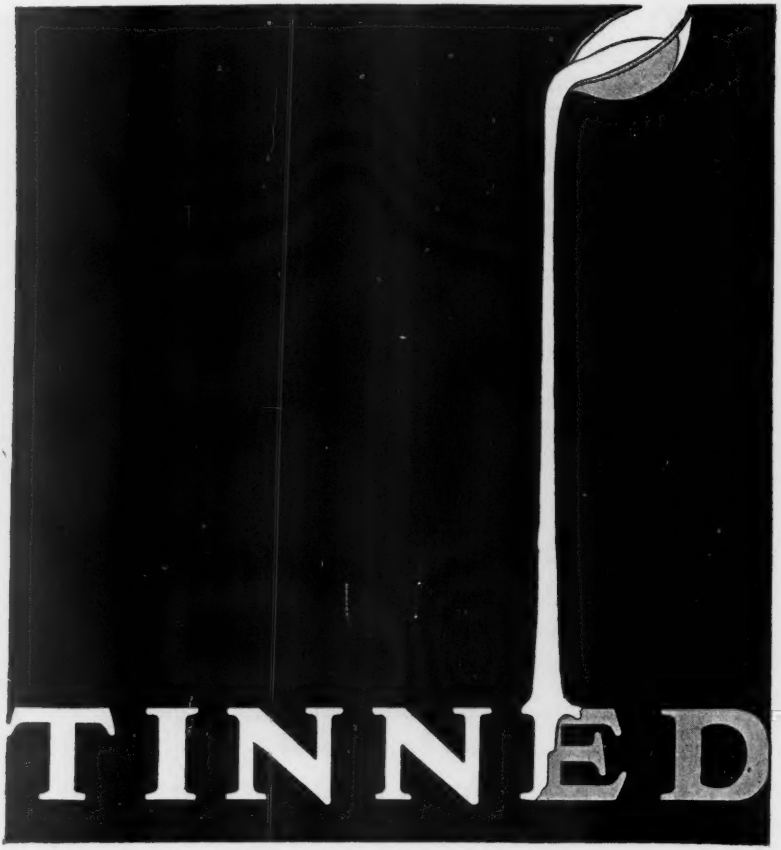

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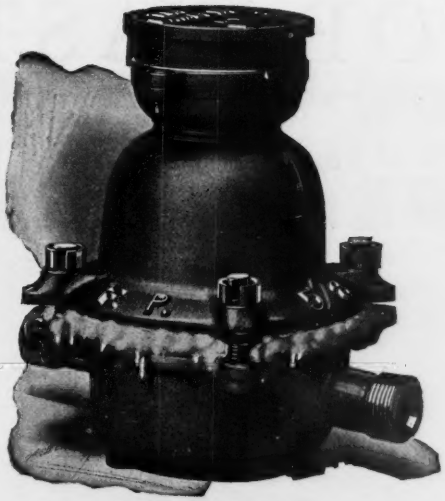

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Here is an actual photograph of a LAMBERT Frost-proof Meter which has been frozen to an extent that would put the ordinary meter completely out of commission.

This is made possible by a patented, non-corrosive yielding bolt device which allows the upper and lower casing, disc chamber and gear train to part without damaging the meter in any way. Five minutes' labor the only repair cost.

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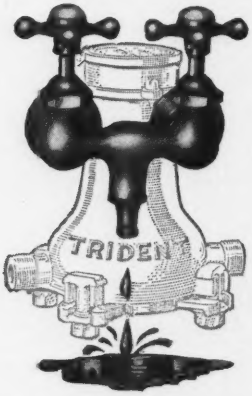

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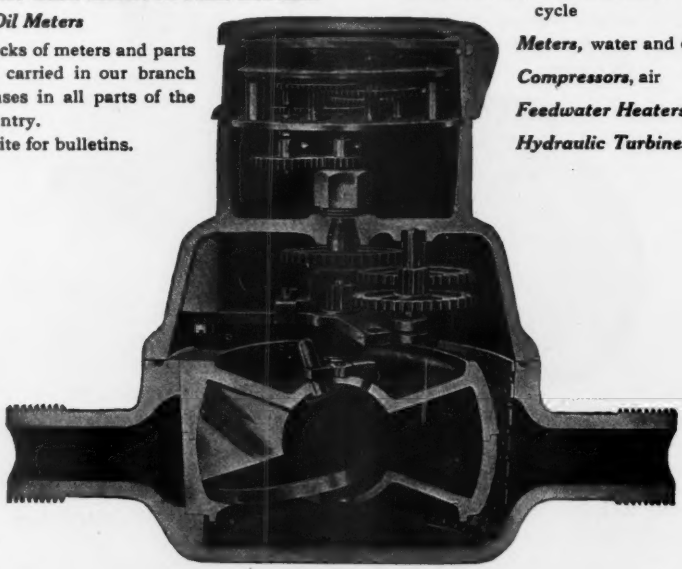

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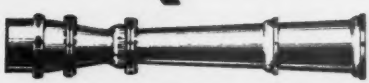
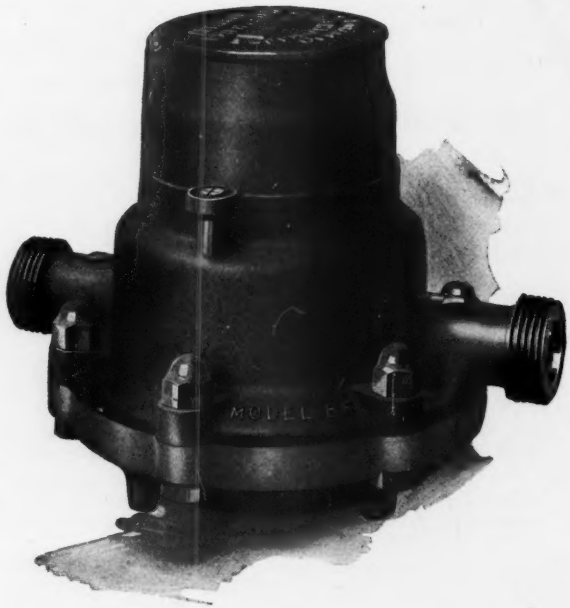


AMERICAN AND NIAGARA WATER METERS



American and Niagara meters are made in solid casing types and frost bottom types. The illustration above shows a $^5/_8$" x $^3/_4$" meter of the frost bottom type. Those meters having bronze outside casings are known as Americans and those having galvanized cast-iron outside casings are Niagaras. The works in all the different casings are of one best model and interchangeable. The registers may be either round reading or straight reading and may indicate cubic feet, U. S. gallons, imperial gallons or litres. All Niagara and American meters are tested and adjusted according to the requirements of the Standard Specifications for water meters adopted by the New England Water Works Association and the American Water Works Association.

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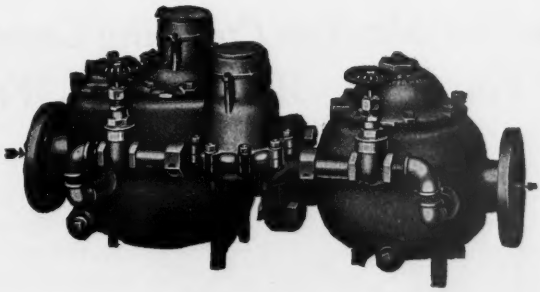

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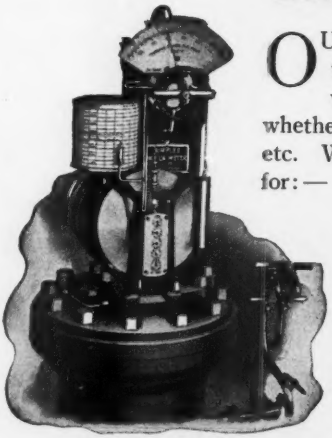

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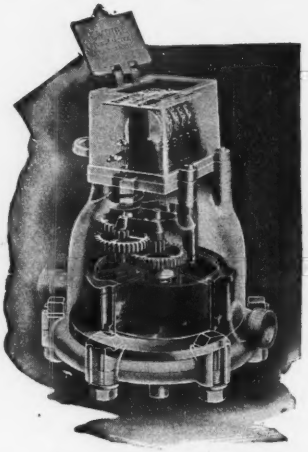

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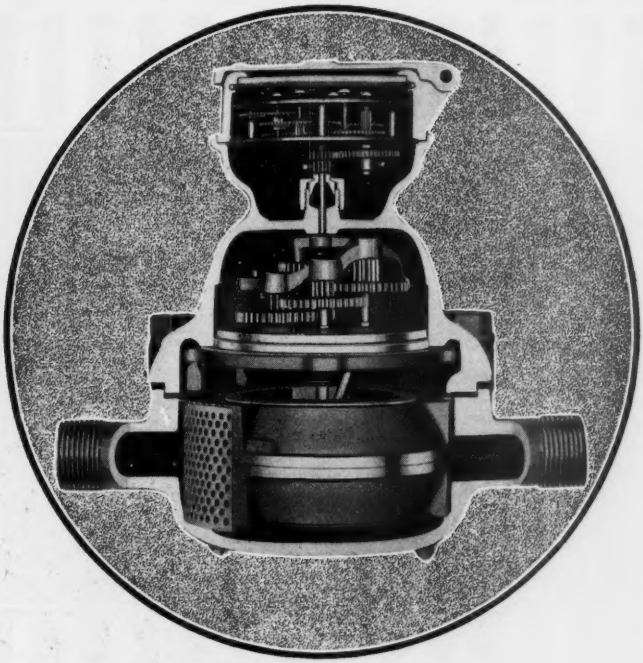

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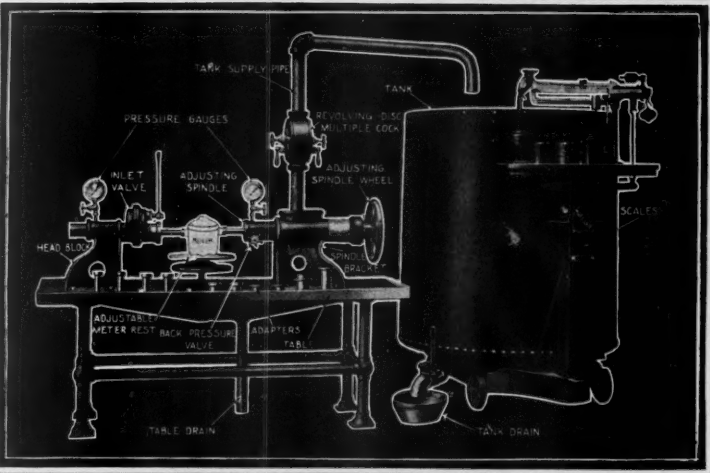

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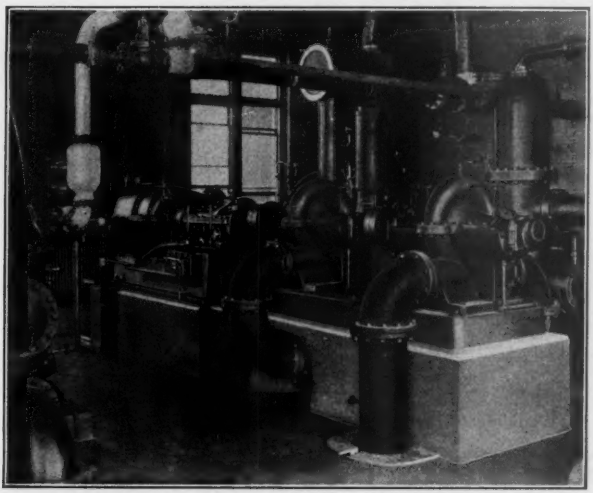

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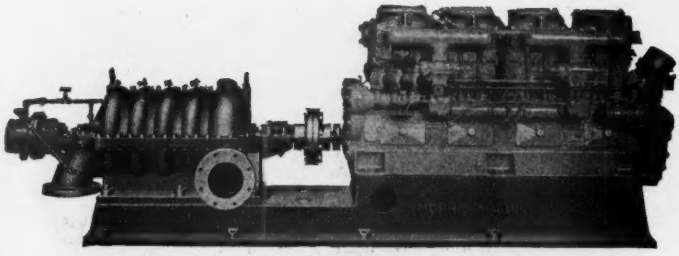

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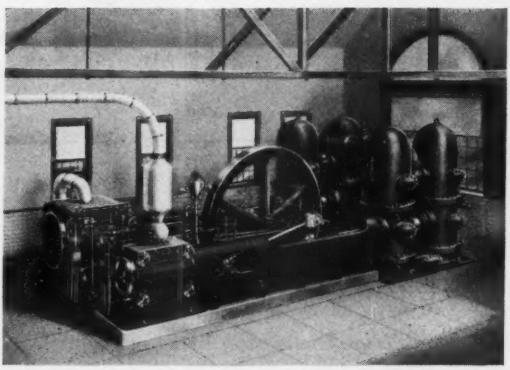


Murray High Duty Crank and Fly Wheel Pumping Engine, Opposed Type

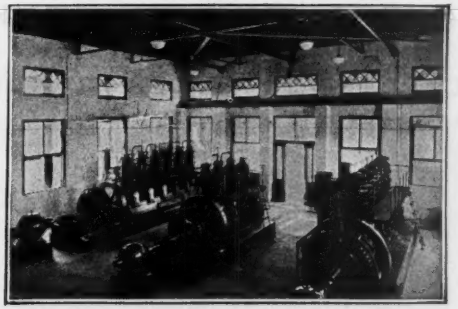
Engineers, Iron Founders, Boiler Makers

Corliss and Una-Flow Engines

Water-Tube, Fire-Tube and Internal-Furnace Boilers

Builders of Complete Power Plants

PLEASE SEND US YOUR SPECIFICATIONS AND CALLS FOR BIDS



Low cost power for municipal plants

The following cities were among those installing F-M equipment during the past year:

Salem, N. H.
Medway, Mass.
Onset, Mass.
Wareham, Mass.
Brant Rock, Mass.
Cherry Valley, Mass.
Milford, N. H.
Beach Haven, N. J.
Millsboro, Del.
Middletown, Del.

Many municipal plants have discovered that their rates cannot keep up with the excessive operating costs of antiquated power units. And in Fairbanks-Morse Diesel Engine economy they have found a way to make profits where formerly they were losing money.

In a large number of plants, F-M Diesel units have been installed in conjunction with complete F-M pumping and power equipment, including F-M alternators, motors, pumps, and auxiliary equipment. Such an installation is represented by the pumping and lighting plant illustrated above. Here undivided responsibility rests with Fairbanks-Morse, and a definite guarantee insures economical and completely satisfactory service.

If your municipal plant is one that is not giving low-cost operation, you will make no mistake in calling on F-M engineers for a report on the savings of an F-M installation. This will obligate you in no way for the service is free.

FAIRBANKS-MORSE & CO., Chicago
Manufacturers of Oil Engines, Pumps and Electrical Machinery
28 Branches throughout the United States at your service.

FAIRBANKS-MORSE

DIESEL ENGINES · PUMPS · MOTORS

Complete power and pumping F M *equipment for municipal plants*

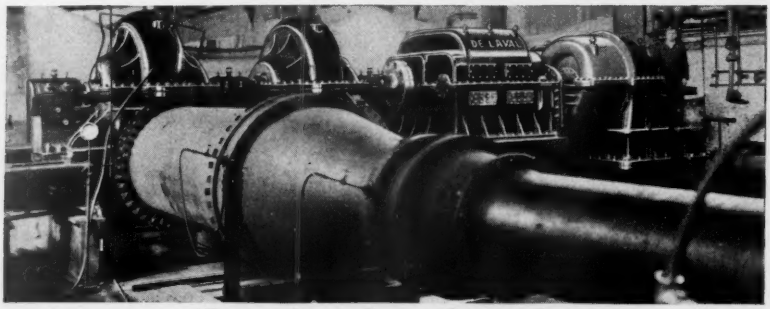
1556

DE LAVAL

CENTRIFUGAL PUMPING EQUIPMENT

is the accepted standard for

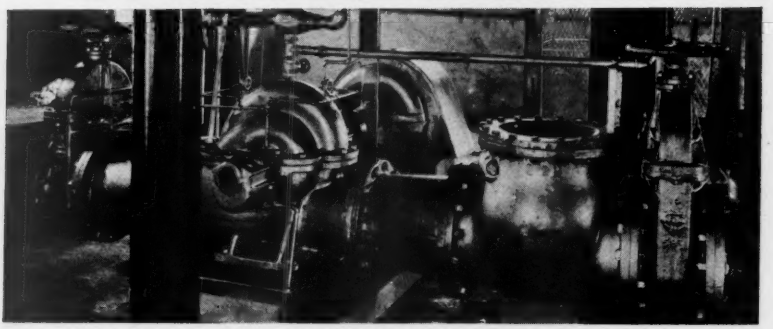
MUNICIPAL WATER WORKS



WESTERN AVENUE PUMPING STATION, CHICAGO.

The largest Municipal steam turbine driven centrifugal pumping unit in the world delivering 75 million gallons per day against 150 feet head.
City of Chicago has fourteen large DE LAVAL pumping units.

TYPICAL NEW ENGLAND INSTALLATION



MILLVALE STATION, HAVERHILL, MASS.

New 7 million DE LAVAL motor-driven pump including the furnishing and erection of transformers and switchboard equipment. On test after installation this pump delivered water at rate of 7,800,000 gallons per day. Another DE LAVAL unit is on order for Kenoza Station, Haverhill.

Recent DE LAVAL municipal water works contracts include New England installations at Canton, Mass., and Millis, Mass.

Ask for De Laval Publication.

TURBINE EQUIPMENT CO. *of* NEW ENGLAND

CHAMBER OF COMMERCE BUILDING

80 Federal St., Boston

NEW ENGLAND REPRESENTATIVE FOR

DE LAVAL STEAM TURBINE COMPANY

Trenton, N. J.

Chlorination

Manual Control Solution Feed Chlorinator —Type MSP

A new rugged apparatus in which the Chlorine is measured under a Vacuum

has become standard practice for the sterilization of water,—the sanitation of swimming pools,—the disinfection of sewage,—the elimination of noxious odors,—and for many other purposes,—largely because of the accuracy and reliability of W&T Chlorine Control Apparatus.

¶ Chlorination of drinking water is not only unsurpassed community health insurance but it is downright good business insurance,—in view of the recent tendency of the Courts* to award damages to persons stricken with intestinal disease caused by polluted water.

*See Engineering News Record, Vol. 97, No. 1, p. 30.

"The only safe water is a sterilized water"

WALLACE & TIERNAN
COMPANY, INCORPORATED
NEWARK , NEW JERSEY

NEW YORK CHICAGO KNOXVILLE SAN FRANCISCO MINNEAPOLIS PITTSBURGH
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SA 5

Founded 1853 Incorporated 1863

MERRIMAC CHEMICAL 1863 COMPANY

FILTER ALUM

Aluminum Sulphate

A basic, uniform product which has been used successfully by the leading water filtration plants in New England for many years.

Our location and shipping facilities place us in a position to offer insurpassable service and make us the logical source of supply for all filter plants in New England.

The aid and advice of our technical staff has often proved of great value to our customers. It is always at their service.

MERRIMAC CHEMICAL CO.

148 STATE ST., BOSTON, MASS.

Works:

EVERETT, MASS. WOBURN, MASS.

IN CHICAGO

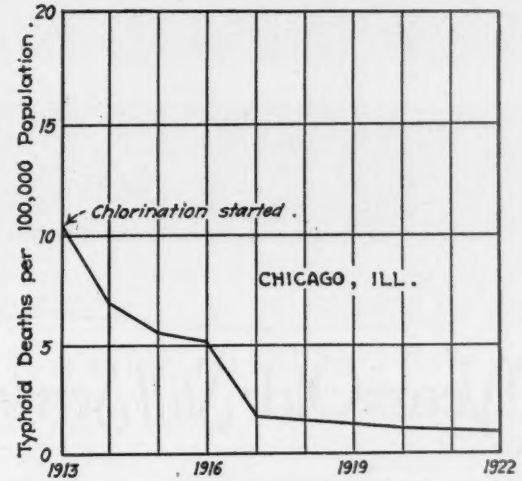


DIAGRAM SHOWS REDUCTION IN TYPHOID FEVER DEATH RATE AFTER INSTALLATION OF CHLORINE

Ask for

WHITE MOUNTAIN BRAND LIQUID CHLORINE

LINDER & MEYER

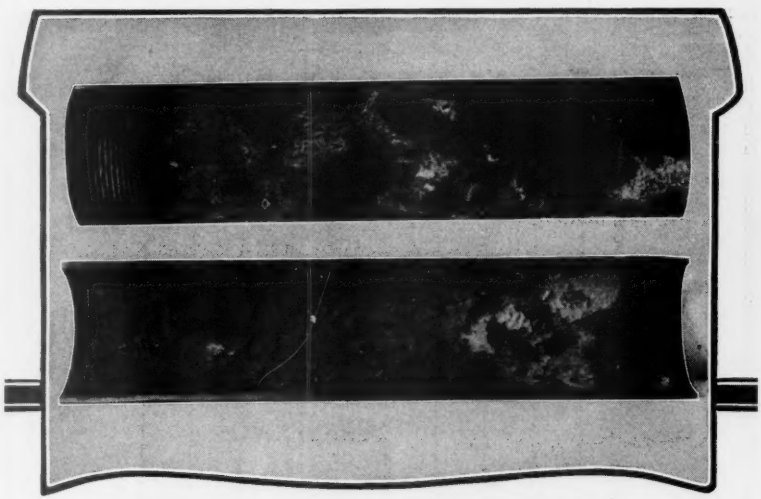
ESTABLISHED 1848

89 STATE STREET, BOSTON, MASS.

Selling Agents for

THE BROWN COMPANY

BERLIN, N. H.



40 Years Old—Still Serving!

In the life of a pipe line, forty years is a long time — particularly if it is spent underground, subject within and without to corrosive onslaughts.

The pipe that can stand it is the pipe for service lines. That genuine wrought iron pipe has the necessary endurance is clearly demonstrated by service records all over the country of which the above photograph is an interesting example.

Here is a two-foot section from a line laid in 1886 by the Atchison Water Co. It is still good. It was removed simply to admit a valve. The line as a whole is in its 41st year of constant, uninterrupted service.

For sixty years, Byers has made pipe from genuine wrought iron. Its quality today is no less than that which has already defied rust for two, even three generations. Such, surely, is the ideal pipe for service lines.

A. M. BYERS COMPANY

Established 1864 **Pittsburgh, Pa.**

BYERS PIPE

GENUINE WROUGHT IRON

W. B. Hubbard & Sons Co.

FRANK W. HUBBARD, President-Treasurer
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WATER WORKS SUPPLIES

176 Oliver Street, Boston, Mass.

PIERCE-PERRY CO.

SUCCESSORS TO
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JOBBERS OF
Heating and Plumbing Supplies
Steel, Wrought Iron and Brass Pipe
Water Works Materials

DISTRIBUTORS OF
Hoffman Valves and Controlled Heat Equipment

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BOSTON PIPE & FITTINGS CO.

WHOLESALE JOBBERS

Byers Genuine Wrought Iron Pipe

National Pipe

COMPLETE LINE OF WATER WORKS SUPPLIES

273-279 CONGRESS ST., BOSTON

We Carry in BOSTON STOCK for Immediate Shipment

CAST IRON BELL AND SPIGOT WATER PIPE AND FITTINGS
FLANGED PIPE in full and short lengths
WROUGHT PIPE

FRED A. HOUDLETTE & SON
(Incorporated)
93 Broad Street, Boston, Mass.
Quotations furnished promptly for shipment from Foundry

CEMENT LINED SERVICE PIPE

With Specially Adapted Lead-lined Fittings

Also Curb Cocks which eliminate Iron to Brass Corrosion both inside and out.

CEMENT LINED PIPE CO.
LYNN, MASS.

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Manufacturers of and Dealers in
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Byers' Wrought Iron Pipe
Service and Valve Boxes
Cast Iron Pipe and Fittings

287 CONGRESS ST., BOSTON, MASS.
Telephone, Liberty 1350

Ware Coupling & Nipple Co.

WARE, MASS.

Grip Pipe Fittings and Brass Nipples

R. D. WOOD & CO.

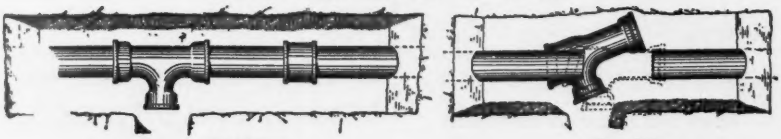
400 CHESTNUT STREET, PHILADELPHIA, PA.

Engineers, Iron Founders and Machinists

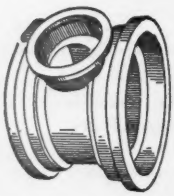
HYDRAULIC VALVES and MACHINERY

Cast Iron Pipe

CUTTING-IN TEES



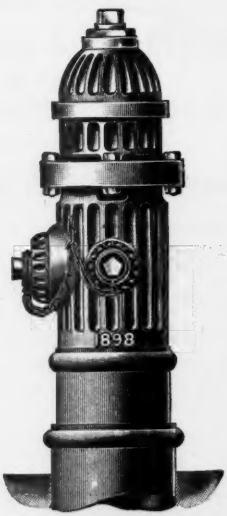
Old Way *Our Way*



Connections economically and easily made with one fitting. Saves sleeve, cuts, lead and unnecessary work and material.

"Reduced Specials"

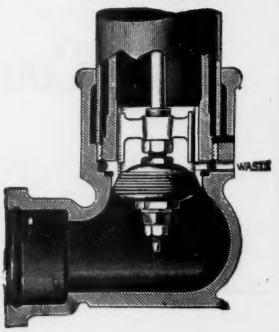
Cost of fittings reduced from 25% to 50%. Full strength. Deep bells. Convenient to handle. Sold by the piece.



Mathews Fire Hydrants

A half century of use has established their reputation as being the most economical, durable and simple hydrant.

Number in use exceeds total of all other makes combined.



Gate Valves

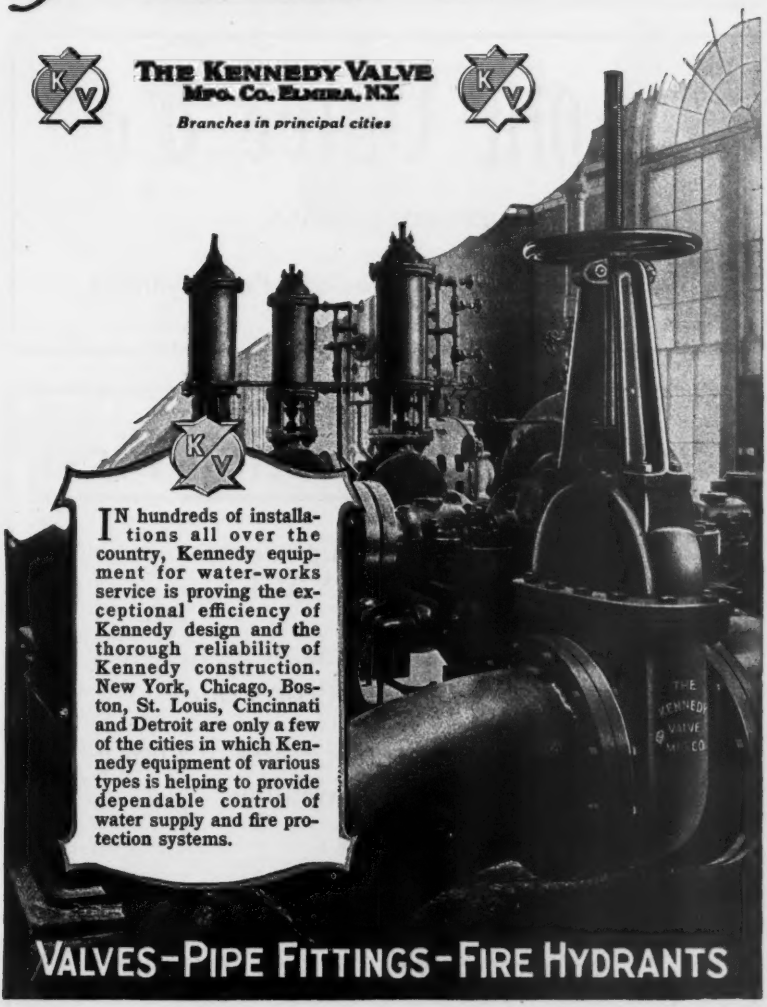
R. D. WOOD & CO. STANDARD
DOUBLE DISK
ANTI-FRICTION
EXTRA WEIGHT, FINISH
AND MATERIAL

KENNEDY

for water-works service

THE KENNEDY VALVE MFG. CO. ELMIRA, N.Y.

Branches in principal cities



IN hundreds of installations all over the country, Kennedy equipment for water-works service is proving the exceptional efficiency of Kennedy design and the thorough reliability of Kennedy construction. New York, Chicago, Boston, St. Louis, Cincinnati and Detroit are only a few of the cities in which Kennedy equipment of various types is helping to provide dependable control of water supply and fire protection systems.

VALVES-PIPE FITTINGS-FIRE HYDRANTS

Automatic Pressure Control Valves
Feed Water Filters
Portable Fire Hydrant Heads
Hydraulic Engines
Hydraulic Booster Pumps

ROSS VALVE MFG. CO., INC. TROY, N. Y.
ESTABLISHED 1879

Coffin Valve Co.

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Sluice Gates, Gate Valves and Fire Hydrants

Health and Protection First

Water delivered through dirty pipes may be a MENACE.

Incrusted water pipes mean inefficiency and loss of Fire Protection.

We Guarantee the Results of Our Method of Cleaning.

WRITE US.

National Water Main Cleaning Co.

50 Church Street New York City

LUDLOW VALVE MFG. CO.

MANUFACTURERS OF

VALVES and FIRE HYDRANTS

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.

The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.

DOUBLE AND SINGLE GATE **VALVES,**

ALSO CHECK **VALVES,**

FOOT **VALVES.**

FIRE HYDRANTS.

YARD, WASH, AND FLUSH HYDRANTS.

☞ SEND FOR CIRCULARS ☜

OFFICE AND WORKS: FOOT OF ADAMS STREET, TROY, N. Y.

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62 GOLD ST.	HARRISON BLDG.	1112 TREMONT BLDG.	1ST NAT. BANK BLDG.	THE ROOKERY	R. A. LONG BLDG.

The Knuckle Joint Principle in Genuine "Rensselaer" Improved "Corey" Fire Hydrants—Means Ease of Operation

BECAUSE this principle gives great power to open or close the gate just when it is needed, and speed in movement when power is unnecessary.

The first turn of the spindle, when the gate is open, moves the valve nearly two inches, after which the speed decreases and power throughout the knuckle joint increases, until at the time of closing the valve moves scarcely one-sixteenth of an inch at each turn of the spindle, eliminating danger from water hammer when closing hydrant.

The gate is closed very tight with slight application of power to the wrench by the operator. The drip valve in the Corey Fire Hydrant prevents freezing. No accident or damage to property can occur with this hydrant by flooding the streets where runaway teams or other accident breaks off or otherwise injures the hydrant standpipe, if hydrant was properly closed at time of accident.

It will be readily seen that the hydrant gate is held in position when shut by the four arms forming braces between the back of the hydrant and the seat, consequently the hydrant barrel can be broken completely off above the ground, but the valves remain tight.

Write for copy of our Hydrant Book No. 9.

CHARLES L. BROWN,

New England Sales Manager, Lock Box 2, Northboro, Mass.

RENSSELAER VALVE COMPANY

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THE CHAPMAN VALVE MANUFACTURING COMPANY

Manufacturers of

Gate Valves Drip Valves

Gate Fire Hydrants

Corporation Cocks Curb Cocks

Anderson Couplings

Lead Pipe Connections

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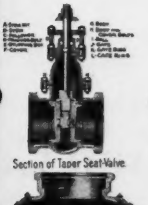
EDDY VALVE CO.

WATERFORD, NEW YORK, U.S.A.

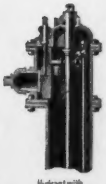
PATENT RUBBER FACED

EDDY FIRE HYDRANT

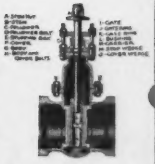
VALVE OPEN—DRIP CLOSED.



Section of Taper Seat-Valve.



Hydrant with Independent Nozzle Cut-off.



Section of Parallel Seat-Valve.

Section of Vertical Check-Valve.

Section of Vertical Foot-Valve.

Horizontal Check-Valve.

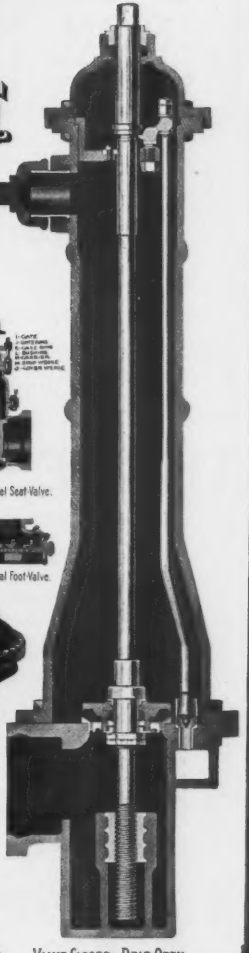
Vertical Foot-Valve.

Hydrant with Water Crane Attachment.

Indicator Post.

Water Crane with Automatic Drip Valve.

All Goods made by the EDDY VALVE COMPANY are manufactured exclusively at WATERFORD. N.Y. U.S.A.



VALVE CLOSED—DRIP OPEN.

EMAUS PIPE FOUNDRY,
DONALDSON IRON CO.,

MANUFACTURERS
...OF...

CAST IRON PIPE

...AND ..

Special Castings for Water and Gas.
Also Flange Pipe, Street Castings,
Manhole Heads and Covers, etc.

JOHN D. ORMROD, President,
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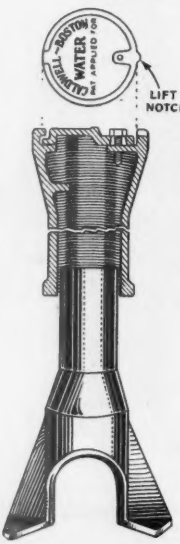
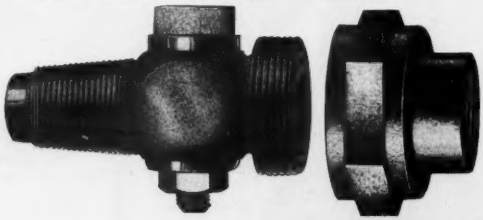
EMAUS,
LEHIGH COUNTY, PA.

The "BEST" Cast Iron Curb Box

Top section is interchangeable with the "Slide Type" Buffalo Box

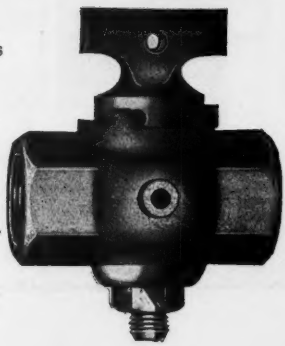


No change necessary in wrench or shut off keys



"CALDWELL" Water Works
Brass Goods, Curb and
Valve Boxes

None better and few as good



GEORGE A. CALDWELL CO.
Mattapan Square
BOSTON, MASS.

60 inch pipe loaded on a barge at our Burlington wharf.

Unusual Shipping Facilities for U. S. Cast Iron Pipe—

THE strategic location of our several plants permits the selection of the most desirable and economical form of transportation by canal, tidewater or rail.

This feature is especially important in handling large contracts promptly and with the lowest possible shipping costs.

As pipe and special castings of standard dimensions are interchangeable, it is possible when necessary to ship orders from two or more works to facilitate filling of the largest contracts.

Write for United States Cast Iron Pipe Handbook. It contains a wealth of valuable data for engineers.

United States Cast Iron Pipe and Foundry Company

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THE A. P. SMITH MANUFACTURING CO.

EAST ORANGE, N. J.

Manufacturers of

Tapping Machines, Fire Hydrants, Water Gates,

Economic Lead Furnaces,

Corporation and Curb Cocks, Brass and Aluminum Castings.

Also General Supplies for Water and Gas Works.

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NICHOLAS ENGEL

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CAST IRON

WATER & GAS PIPES

FLANGE PIPE

Special Castings, Fire Hydrants, Valves

General Foundry and Machine Work

WOOLWORTH BUILDING 233 BROADWAY

NEW YORK CITY

HIGHEST AWARD, GOLD MEDAL,
ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments

use

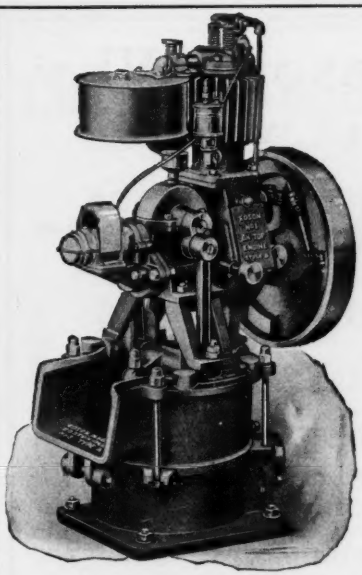
LEAD-LINED IRON and TIN-LINED PIPES

for their service connections

MANUFACTURED BY

Lead Lined Iron Pipe Company

Wakefield ═══ Mass.



STYLE "B" ENGINE – STYLE "A" NO. 3 PUMP
Furnished on Hand Skid or 4-wheel Truck

"On Top" Trench Pump Unit

EDSON

DIAPHRAGM
PUMP SPECIALTIES

Hand and Power Outfits

Try one of our Gasoline Two-Pump
EMERGENCY UNITS

Insist on GENUINE EDSON Pumps,
Suction Hose, Diaphragm
with Bead, etc.

New Catalogue on application

Edson Manufacturing Corp.
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Warren Foundry and Pipe Co.

(Formerly Warren Foundry and Machine Co.)

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201 DEVONSHIRE ST., BOSTON, MASS.
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CAST IRON PIPE

Bell and Spigot Flanged Pipe
Special Castings
Flexible Joint Pipe Cylinders

Water Gas Sewers Culverts

Works, Phillipsburg, N. J.
LARGE STOCK ENABLES US TO MAKE QUICK SHIPMENTS

Twelve Reasons Why

YOU SHOULD USE

Trade "LEADITE" Mark

Registered U. S. Patent Office

FOR

Jointing Water Mains

1. **DURABILITY.** Leadite joints increase in strength with age.
2. **NO CAULKING.** Leadite joints require no caulking, because the Leadite adheres to the pipe, making a water-tight bond.
3. **COMPARATIVE QUANTITIES.** One ton of Leadite is equivalent to four tons of lead.
4. **LABOR SAVING.** Saves caulking charges and digging of large bell-holes, and reduces the cost of trench pumping to the minimum.
5. **COST.** Its use saves 50 to 65 per cent. over lead, owing to the saving effected in material and labor.
6. **TOOLS.** As no caulking is required, fewer tools are needed.
7. **TRANSPORTATION.** Considerable freight charges are saved because Leadite is lighter than lead.
8. **HAULING.** Saves hauling expense on the work because you move only one fourth the weight of jointing material.
9. **FUEL.** Saves fuel because you melt only one ton of material instead of four, and not as much heat is required either.
10. **DELIVERY.** We can make prompt shipments.
11. **DAMAGE SUITS.** Claims for damages caused by joints blowing out are prevented because Leadite joints will not blow out under any pressure.
12. **USERS.** Progressive water works all over the country use Leadite.

WRITE FOR BOOKLET

The LEADITE COMPANY, Inc.

Land Title Building **Philadelphia**

P. E. KELLY, New England Representative

8 TRENT STREET **ARLINGTON, MASS.**

Chadwick-Boston Lead Co.

800 Albany St., Boston

Agents for

The Celebrated "ULCO"

LEAD WOOL

(Every Atom Pure Lead)

For calking pipe joints under the most difficult conditions.

For overhead joints, or in wet places where the use of molten lead is not only impracticable but dangerous — **LEAD WOOL** may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe without danger of a leak.

As compared with the poured joint, in this respect, the superiority of **LEAD WOOL** is apparent.

Manufacturers of

Lead Pipe, Tin Lined Lead Pipe, Pure Block-Tin Pipe, Solder, White Lead and Red Lead.

HIGHEST QUALITY SOFT BRANDS

PIG LEAD

TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND TEN CENTS

PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND TEN CENTS PER POUND

Join Your Water Mains

WITH

LEAD-HYDRO-TITE

TRADEMARK

AND CUT YOUR EXPENSES

50% FIRST COST

50% SMALLER BELL HOLES

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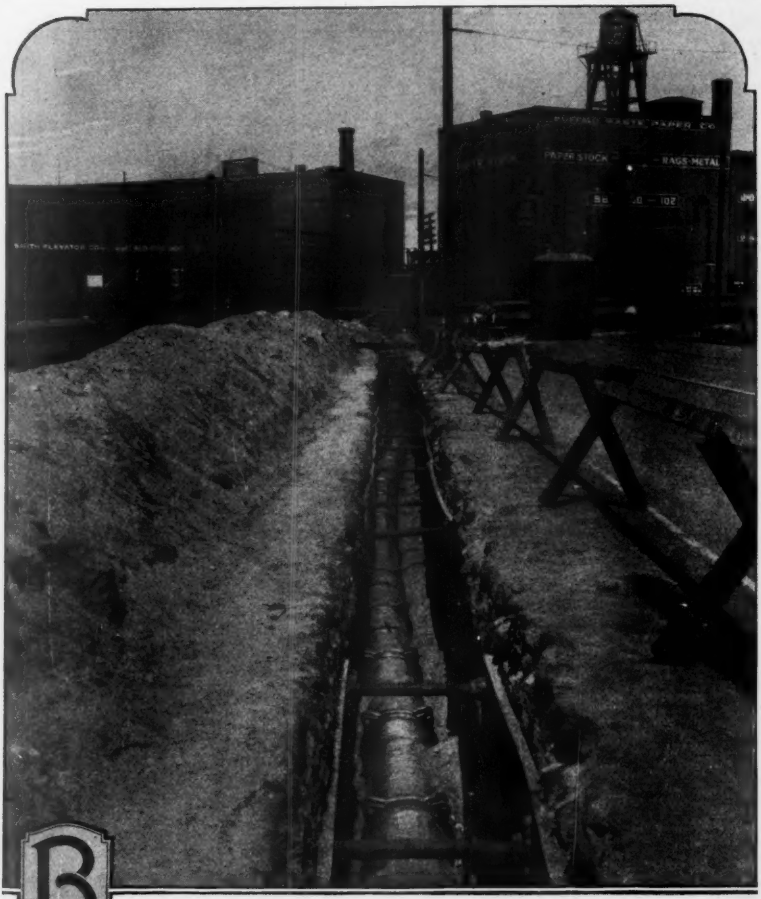

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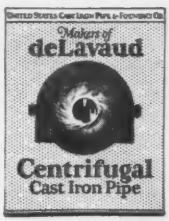

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New England Water Works Association.

ORGANIZED JUNE 12, 1882.

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residing at.....
(City or Town and State)

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(Junior, Member, Corporate or Associate)

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(Place of birth)

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(Finally state present occupation)

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